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THE POSSIBILITY OF COSMIC-RAY HAZARDS IN HIGH ALTITUDE AND SPACE FLIGHT

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SUMMARY

The high-energy radiation which enters the atmosphere produces ionization in any material that it penetrates. Ionization deposited inside living tissue will produce damage leading to the destruction of cells. A preliminary estimate indicates that under the worst conditions, which will be met in flight in and above the atmosphere, the ionization produced in exposed tissue will be only about one-fifth of that which is tolerated in the case of personnel exposed continuously to gamma or X-rays. However, the primary cosmic-radiation includes heavy nuclei of sodium, silicon, iron, etc., and secondary radiation produced in nuclear collisions includes alpha particles and protons of intermediate energy. These radiations produce ionization at a very high concentration along the tracks of the particles. It has been found that a given amount of ionization deposited in this way is as much as thirty times as effective as the same amount of ionization deposited at low concentration along the tracks of electrons resulting from gamma or X-ray absorption. When this is taken into account, it appears that the biological effect of cosmic-radiation on tissues exposed outside the atmosphere may, in the worst instances, exceed that which can be tolerated in continuous prolonged exposure.

Introduction

Some 40 years have elapsed since V. F. Hess put forward his hypothesis that the ionisation which had been observed for many years in the air, both near ground level and with increasing intensity at high altitudes, was caused by penetrating radiations entering our atmosphere from outer space. Since that important discovery, cosmic radiation, as it has become to be called, has been the subject of widespread and intensive study, so that to-day we have a fairly clear idea of the nature of this radiation and the phenomena which it produces in passing through the atmosphere.

The early experiments were carried out by measuring the ionization produced in air contained in sealed vessels (ionization chambers) and one of the first important discoveries was the fact that this increased if the chamber were raised to a high altitude. This indeed, was the factor which led to Hess's hypothesis. When, eventually the measurements were extended to extreme altitudes by suspending the ionization chambers from balloons, it was found that the ionization reached a maximum at an altitude of between 20 and 30 kms. and afterwards dropped off gradually at greater heights. Subsequent measurements have been entended to heights of 160 kms. by means of V.2 flights and it has been confirmed that the ionization does not show any further increase. Fig. 1 shows the results obtained by Millikan, Bowen and Neher,

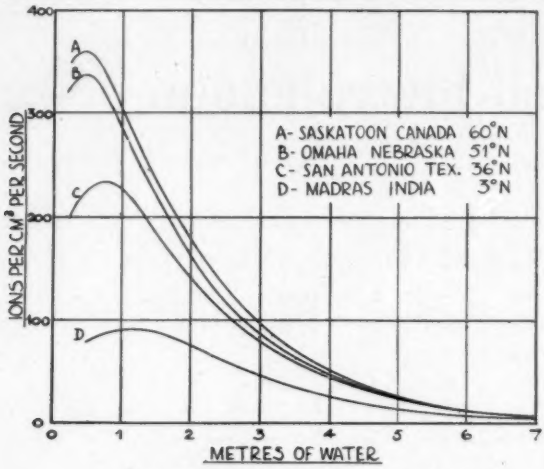

FIG. 1. (From I. S. Bowen, *loc. cit.*)

shortly before the Second World War. The graph shows the intensity of ionization, in terms of pairs of ions produced per second in a cubic centimetre of air at normal temperature and pressure. This is plotted against the depth in the atmosphere in equivalent thicknesses of water (the whole depth of the atmosphere is equivalent to approximately 10 metres of water).

The intensity of ionization produced at sea level is about 2 ion pairs/cm.^{3} of normal air per second, so it will be observed from Fig. 1 that an increase of nearly 200 fold over the sea level value occurs at the peak intensity. An interesting feature which is revealed in this diagram, is the dependence of the ionization intensity upon the geomagnetic latitude (i.e. the latitude with respect to the Earth's magnetic poles at the point of measurement). This was interpreted as meaning that the magnetic field of the Earth exerts a marked influence upon the intensity of the cosmic radiation reaching the top of the atmosphere. It meant that some, if not all of the incident (primary) radiation, consisted of charged particles and not high energy gamma radiation as had been previously supposed. The magnetic field of the Earth deflects charged particles and if the velocity or kinetic energy of a particle is too low, it may be prevented entirely from reaching the atmosphere in certain regions. The effect is most marked for the case of particles reaching the earth at the geomagnetic equator, and depends upon the direction in which the particle is approaching and the sign of the charge on the particle. If the particle is an electron (negative charge) then it may approach the atmosphere at the geomagnetic equator from the East, at grazing incidence provided that its energy is 10 Bev. (10^{10} electron volts) or greater; it might approach at any angle from the Eastern horizon, up to the zenith, if its energy is 15 Bev., but from the Western horizon, it could reach the atmosphere at the geomagnetic equator only if its energy were 60 Bev. In the case of protons the corresponding energies are about 1 Bev. lower and

the directions are reversed. The necessary energies decrease with increase of magnetic latitude, and at the magnetic poles particles of all energies may arrive in any direction.

Arising out of these features of the influence of the Earth's magnetic field on charged particles, it was shown that the particles reaching the Earth were positively charged, since there was found to be a clear preference for the Western approach. The initial conclusion was that the primary cosmic radiation consisted of protons. Furthermore, there appears to be a lower limit to the energy of the particles reaching the Earth, which is revealed by the fact that the intensity of the radiation in the atmosphere does not increase with magnetic latitude beyond 58°. This means in fact, that there cannot be protons with energy less than about 560 Mev.[1a] present in the incoming radiation. The reason for this cut-off is not certain. One explanation attributes it to the existence of a strong magnetic field about the sun, which screens the Earth's orbit from protons of lower energy, but this is by no means certain.

It appears then, that cosmic-ray phenomena arise from positive particles entering our atmosphere with very great energy, and that one outcome of this radiation is the production of ionization in the atmosphere. The ionizing power increases with altitude and is a maximum somewhere between 20 and 30 kms. above the surface. The radiation will of course produce ionization in any material it traverses. If this material happens to be living tissue, then the ionization will lead to damage in the tissue. It is natural to enquire whether this damage is likely to reach a serious degree if the tissue is exposed at very high altitudes or above the atmosphere. This is becoming particularly relevant as the limiting altitude of manned aircraft is pushed higher, and as space flight becomes imminent. The matter has been the subject of a detailed study by H. J. Schaefer and much of this report is based upon his observations.

The ionization produced by radiation and high energy charged particles as they pass through living tissue is the agency leading to biological damage. It is natural, therefore, to measure the "dosage" imparted to the tissue in terms of the ionization produced in the tissue. Actually we are not able to measure the radiation produced inside tissue, so we measure instead the ionization produced in an air-filled ionization chamber, and rely upon the fact that this is proportional to that which would be produced by the same radiation inside living matter. We employ as a measure of radiation dosage the Röntgen or *r*-unit. This is the amount of irradiation which will produce $2{\cdot}1 \times 10^9$ pairs of ions in a cubic centimetre of air at 0° C. and 760 mm. pressure. This corresponds to the release of 83 ergs per gram of tissue under the same irradiation.

The personnel working in establishments where there is a hazard due to gamma or X-rays, are protected from radiation injury by the strict observation of a fixed upper limit on the exposure which they may receive. In this country, this upper limit, or tolerance, is 0·5r per working week. A worker who is regularly exposed to gamma or X-radiation must not repeatedly exceed this dosage.

If we now re-examine Fig. 1, we see that the maximum ionization rate recorded at high altitude and at geomagnetic latitude 60° N. was just 360 ion

pairs per cubic centimeter per second in standard air. At this rate, it would take $2{\cdot}9 \times 10^6$ seconds, or nearly 5 weeks to accumulate the weekly tolerance dose of 0·5r and, at the geomagnetic equator, at the altitude of maximum ionization rate, it would require nearly 20 weeks exposure. On this basis, therefore, the worst possible state of affairs represents only one-fifth of a tolerance, and we could immediately dismiss cosmic-radiation as constituting no hazard to the high-flying airman or spaceman. However, before we so easily brush this hazard aside, we must reflect that the quoted tolerance of 0·5r applies to gamma rays and X-radiation, and cannot for example, be applied to neutrons or alpha-particles. The fact is, as we shall detail later, that the damage produced by radiation, depends not only upon the amount of ionisation which it produces, but upon the way in which it produces it, in particular by the density of ionization along the tracks of the ionizing particles. Certain types of radiation damage are much more sensitive to dense ionization than to light ionization. In such cases, densely ionizing alpha particles produce more damage than lightly ionizing gamma rays, for the same total ionization dosage. It follows, therefore, that before we can correctly assess the hazard of cosmic-radiation, we must examine more closely their nature, particularly the ionization density along the tracks of the various cosmic-ray particles.

The Primary Radiation

The view that the primary cosmic radiation consists of positively charged particles, has been widely held for many years. Until recently it was generally supposed that these positive particles consisted of protons, though the possible existence of helium nuclei (alpha particles) and even heavier nuclei was suggested. In 1948 it was proved[2] as the result of the exposure of cloud chambers and photographic plates at high altitudes, that highly ionized, heavy atoms were present among the particles reaching the top of our atmosphere. It is now known that the cosmic-ray primaries are a mixture of nuclei ranging from protons up to iron nuclei (atomic number $Z = 26$). Heavier nuclei than iron may be present too, but they have not been definitely identified so far. The various nuclear species appear to be present in the incoming flux of particles roughly in proportion to the abundances with which they are believed to exist in the universe. It would appear, in fact, as though nature were bombarding us with a representative sample of her wares. Van Allen[3] gives the following table of relative intensities of the different incoming species, summarizing data obtained by various groups, working at geomagnetic latitudes from 30° N. to 55° N.

TABLE I

Element	Relative intensity
H	4,000
He	950
C	11
N	11
O	11
Na + Mg + Al + Si	6·0
S + A + Ca	2·3
Fe	1·0

The absolute intensity of particles entering the atmosphere, will of course depend upon the geomagnetic latitude because of the effect of the Earth's

magnetic field. We should expect the intensity of protons to be affected more by this field than the heavier nuclei, since the ratio of the electric charge to the mass of a proton is greater than that for helium and the heavier nuclei. However, the ratios given in Table I can be considered to hold roughly at all latitudes. According to Van Allen, the incoming current of cosmic ray particles, at 41° geomagnetic latitude, is 730×10^{-4} per cm.^{2} per second steradian, or from the whole hemisphere about 0·46 particles per cm.^{2} per second. At the geomagnetic equator the intensity of incoming particles is only about a third of this value, while at geomagetic latitudes greater than 55°, the flux of particles is about three times greater.

An interesting fact has emerged from measurements upon the energy or velocity distribution of the cosmic ray primaries. It has been found that the velocity distribution of the different nuclear species is more or less the same for all species. Thus a curve giving, for example, the velocity distribution of the incoming helium nuclei, looks the same as that for iron nuclei. It is sometimes customary to refer to the energy per nucleon of a cosmic-ray particle rather than its velocity. This is the kinetic energy of the given nucleus divided by the number of nucleons (neutrons and protons) which constitute it. In the case of an iron nucleus, for example, the energy per nucleon is its kinetic energy divided by 56. The statement that the velocity distribution is independent of the type of cosmic ray particle is equivalent to saying that the distribution of energies per nucleon is the same for all types of cosmic ray particles.

Kaplon, Peters, Reynolds and Ritson[4] have recently published the results of a series of measurements on the energy spectrum of cosmic-ray primaries. According to these workers, the distribution in energy per nucleon, for all types of particles from helium to iron inclusively, takes the form:

$$N(\epsilon) = K_z/(1 + \epsilon)^{1.35}$$

Where ϵ is the energy per nucleon in Bev., K_z is a constant proportional to the intensity of the type of particle Z in question, and $N(\epsilon)$ refers to the number of particles with energy greater than ϵ per nucleon.

The spectrum of the primary protons has been determined by Winckler as:

$$N(\epsilon) = K_1/(1 + \epsilon)^{1.07}$$

This distribution differs slightly from that for the heavier particles but not greatly. The distributions for the various types of particles, with the appropriate intensities, are shown in Fig. 2, which is reproduced from the report of Kaplon, *et al.* (*loc. cit.*). At a given geomagnetic latitude the curves shown extend upwards from a minimum value of ϵ, which corresponds to the cut-off due to the Earth's magnetic field. (These cut-offs are not indicated.) The intensities in this figure do not agree completely with those given by Van Allen, which we have quoted previously, but the difference is not very significant.

The Secondary Processes

The fate of the primary cosmic rays when they enter the atmosphere or any other matter which lies in their path is complex. A great variety of phenomena occur, which occupy the attention of a large percentage of the

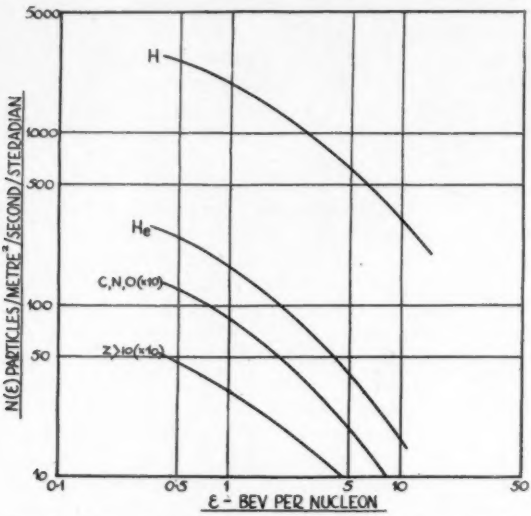

FIG. 2. Integral energy distribution of cosmic ray primaries (from Kaplon *et al.* (*loc. cit.*)).

world's physicists at the present time. We are primarily interested in the manner in which the ionization is finally produced, and since this involves a knowledge of the types of ionizing particle involved, it is necessary to examine, not only the nature of the primary rays, but also the nature of secondary charged particles.

When a primary cosmic ray particle enters matter, such as the air around our planet or any solid object, etc., flying high in or above the atmosphere it has two main processes by which it may give up its great kinetic energy.

(*a*) It may gradually give up its energy by ionizing and exciting the atoms of the material through which it passes. About 30 electron volts are lost for each pair of ions (a positively charged atom and the ejected electron) so produced.

(*b*) It may collide with an atomic nucleus, producing a violent nuclear reaction, usually referred to as a "star." The energy of the collision is distributed among the fragments of the colliding nuclei.

While it is possible that the primary particle may give up *all* its energy by the first process, this is unlikely in the case of particles of such high energy, and most cosmic-ray primaries end their careers in processes of type (*b*), only a few per cent. being brought to rest by the ionization process. In general the primary gives up some proportion of its energy in ionization and then transfers its energy to a number of secondary particles resulting from a nuclear collision.

The second type of interaction (*b*) is the starting point of a sequence of events which yields a great variety of secondary particles. The primary

particle may pass right through the nucleus, or if it is itself a large nucleus, one or more fragments of it may continue along the original path with approximately the velocity of the original nucleus. These may be accompanied by knock-on particles (or shower particles) which also move with velocities comparable to the original particle in the forward direction. In addition to these particles, there are medium or low energy particles which "evaporate" off the highly excited remnant of the target nucleus.

The average excitation energy of the remnant of the target nucleus is at least 200 Mev. If the target nucleus is a fairly light atom (carbon, nitrogen oxygen) the evaporation yields an average of about 3 "charged" particles of which, on an average, about half are alpha particles with energy of 10 Mev. or more, the remainder being mainly protons, but deuterons and tritons may also occur.

The knock-on particles are of two types: (i) neutrons and protons, (ii) created particles (mainly pi-mesons or pions, which have a mass of 280 times the electron's mass). The neutrons have sufficient energy to produce further stars when they eventually collide with nuclei and the protons, which are of course indistinguishable from primary protons, may also produce further stars. These later stars tend to emit evaporation particles only, unless the knock-on particles which produced them are especially energetic.

The pi-mesons may be positively or negatively charged or neutral. The neutral pi-meson dissociates almost immediately into two high energy gamma rays (photons), which initiate the photon-electron cascades that are frequently observed in cosmic ray processes. The positively charged pi-meson decays into a positive mu-meson (200 times as massive as an electron) while the negative pi-meson may decay into a negative mu-meson or may be captured by a nucleus, the latter process leading to a further star.

Both the negative and positive mu-mesons decay with a mean lifetime of 2×10^{-6} seconds, when they are at rest (the observed lifetime is much longer when they are moving with speeds comparable to that of light). The product of the disintegration is an electron or positron depending upon the sign of the charge on the mu-meson.

The final remnants of cosmic-radiation which we observe at sea level are mainly electrons, mu-mesons, gamma rays and a proportionately small component of protons and neutrons. The mu-mesons are extremely penetrating and at great depths below the ground these particles can still be observed. Only the very high energy cosmic ray primaries produce secondaries which penetrate to sea level. The less energetic particles, which reach the atmosphere at high geomagnetic latitudes only, do not produce any measurable effect at sea level. The result of this is that the large latitude effect on the primaries is not reflected very markedly by the sea level phenomena, which show only a small latitude variation.

The various types of secondary particles which have been mentioned above do not complete the list of known particles. A number of heavy unstable particles with masses about a thousand times as great as the electron and even greater than the mass of the proton, are known to exist. These are comparatively rare and do not need to be taken into account here.

The Cross Section for Star Production

The probability that a primary will undergo a star-producing collision, is more or less determined by the geometric cross sections of the target nucleus and the primary particle. The actual expression for the effective collision cross section is:

$$\sigma = \pi(R_p + R_t - 2\Delta R)^2$$

where R_p and R_t are respectively the "radii" of the primary and target nucleus. ΔR is a small correction to allow for the fact that collisions appear to require a small overlap to become effective, Kaplon *et al.* (*loc. cit.*) give the value of ΔR as $1{\cdot}0 \times 10^{-13}$ cms. The "radius" of an atomic nucleus is given by:

$$R = 1{\cdot}45 \times 10^{-13} A^{1/3}$$

where A is the mass of the target nucleus in terms of the mass of the proton. There are $6 \times 10^{23}/A$ nuclei in a gram of material made up of such nuclei, and we can see therefore that the mean free path of a primary, in a target material of type T, expressed in terms of grams per square centimetre* is:—

$$l_t = \frac{A_t}{6 \times 10^{23}\sigma_t}$$

The ensuing table gives the mean free paths of various types of primary in air and iron.

TABLE II

Primary	l_t in grams per square centimetre	
	Air	Iron
H	85	120
He	51	90
N	29	60
Mg	23	50
Fe	15	37

It will be observed from this that, mass for mass, air is a better stopper than iron.

Since most of the cosmic ray primaries are protons and alpha particles, we should expect the average mean free path of the primaries to be somewhere between the first two values of the Air-column in Table 2. If all the primaries entered the atmosphere normally, then the rate of star production would fall off exponentially with an attentuation length equal to l_t, as one proceeded downward through the atmosphere. Since the primaries enter the atmosphere in all directions, the actual fall-off is somewhat more complicated. In addition, as we have seen, the primaries eject knock-on particles from the target nuclei, and these (particularly the neutrons and negative pions) can themselves produce stars. The result is that the actual rate of production of stars at first increases (because the number of star-producing particles increases) and then

* The mean free path in grams per square centimetre is equal to the m.f.p. in centimetres $\times$ the density of the target material in grams per cubic centimetre.

eventually decreases exponentially with an attenuation length of about 140 grams per square centimetre. The increase in star production rate is illustrated by a survey of Freier, Ney and Oppenheimer,[5] who exposed photographic plates at high altitudes and found that in each cubic centimeter of emulsion there were 1,870 $\pm$ 140 stars produced per day at a depth in the atmosphere corresponding to 50–300 grams per square centimetre of air, but that the daily production of stars was only 880 $\pm$ 90 per cubic centimetre at a depth of 14–24 grams per square centimetre from the top of the atmosphere. The difference was made up almost entirely, by low energy stars which were presumably caused by knock-on particles. A similar effect is observed if a small volume of material exposed outside the atmosphere, is surrounded by an envelope of about 100 grams per square centimetre of some other material. The star rate in the sample is actually increased as a result of its being so enveloped.

The Ionization Produced by Charged Particles

When a charged particle moves through matter, the density of the ionisation produced along its tract depends upon its velocity and the charge which it carries. It does not depend very markedly on any property of the absorbing matter, other than the density of the latter, to which it is proportional. The dependence of the ionization density on the velocity of the particle is complicated, but its dependence on the charge is very simple, the ionization density being in fact proportional to the square of the charge on the particle. Normally, we express this charge in terms of the charge on the electron. Thus the proton, charged mesons, positron and electron, have unit charge, while the nuclei which make up the primary cosmic radiation, have a charge Z (identical with the atomic number of the nucleus in question). The expression for the specific ionization (number of ion pairs per "gram per square centimetre" of path), takes the form:

$$j = \frac{BZ^2 f(v)}{v^2}$$

where $f(v)$ is a very slowly varying function of the particle velocity v, which only changes by a factor of about 2 as v goes from 0·1 c to 0·99 c (c being the velocity of light). $f(v)$ is slightly dependent on the identity of the medium.

B is a constant which is also slightly dependent on the nature of the medium, while Z is, of course, the charge on the particle in terms of the electron's charge.

The quantity $f(v)/v^2$ and therefore j has a minimum at $v = 0{\cdot}97\ c$. The ratio j/j_{min} is plotted against the kinetic energy ϵ for the case of the proton (Fig. 3). The same curve can be used for any primary having a charge Z and a mass number A, simply by multiplying the j-scale by Z^2 and the ϵ-scale by A. Thus in the case of an Fe nucleus ($Z = 26$, $A = 56$) we should multiply all values of j by 676, and expand the ϵ-scale by a factor of 56. The curve can also be used for pi-mesons, mu-mesons and, near the minimum, also for electrons by multiplying the ϵ-scale by 0·152, 0·109 and 0·00054 respectively.

The value of j_{min} is 28,000 ion pairs per gram-per-square centimetre in air, and about double in hydrogen. In human tissue, which is mainly water, the

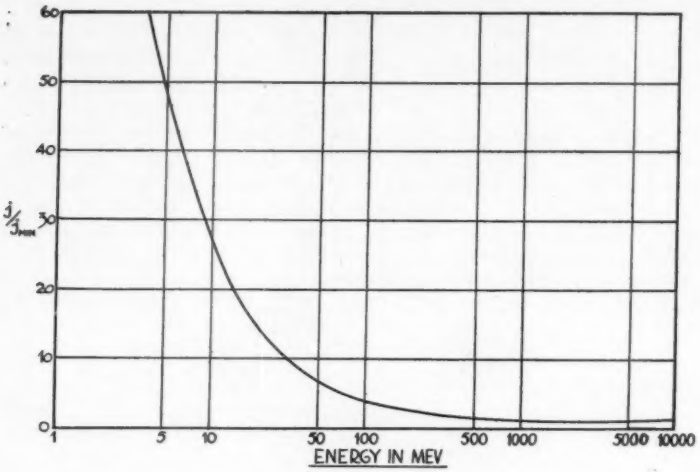

FIG. 3.

value is about 30,000. Since the density of tissue is very nearly unity, this figure represents 30,000 ion pairs per centimeter of track length or, as it is more usually expressed, 3 ion pairs per micron.

We shall now apply this data to the various particles present in cosmic radiation.

(*a*) *Primary Protons.* The protons entering the atmosphere at high latitudes have energies greater than 0·56 Bev. and at the geomagnetic equator, greater than about 13 Bev. Clearly these primary protons produce ionization at minimum density, viz. 3 *ion pairs per micron*, over most of their track lengths.

(*b*) *Primary He Nuclei.* The minimum energies per nucleon, are about 300 Mev. and 8 Bev. at high and low geomagnetic latitudes respectively. In the latter case most of the ionization is produced at near minimum, viz. 12 *ion pairs per micron* and one can say confidently that only a negligible fraction is produced, in either case, at greater than 100 ion pairs per micron (ϵ less than 40 Mev. per nucleon).

(*c*) *Primary C.N.O. Nuclei.* (Average $Z^2 \sim 50$.) The range of energies per nucleon are the same as for the alpha particles. The minimum ionization density is 150 *ion pairs per micron.* All but a very small proportion of the ionization will be produced between this value and about 1,000 ion pairs per micron, most of it near to the minimum value.

(*d*) *Primary Si Nucleus.* ($Z^2 = 196$.) The minimum ionization is about 600 *ion pairs per micron.* An appreciable proportion of the ionization may therefore be expected to occur with a density greater than 1,000 ion pairs per micron.

(*e*) *Primary Fe Nucleus.* ($Z^2 = 676$.) The minimum ionization is about 2,000 *ion pairs per micron.* If these nuclei are slowed down to about 5 Mev. per nucleon, the ion pair density reaches about 100,000 per micron, but of course, only a small fraction of the total track length would be ionized as densely as that.

(*f*) *Knock-on Protons.* Most of the ionization will occur at less *than* 10 *ion pairs per micron* (i.e. energies greater than about 100 Mev.).

(*g*) *Charged Pi and Mu Mesons.* For all practical purposes these particles may be regarded as ionizing at minimum, 3 *ion-pairs per micron.*

(*h*) *Electrons and Gamma-Radiation.* The proportion of electron and positron tracks ionizing above minimum, is negligible. Gamma-radiation only ionizes through secondary electrons and positrons which it produces, and the same remark applies therefore.

(*i*) *Evaporation Protons and Alpha-particles.* About a half of the charged particles in stars occurring in tissue will be alpha-particles with initial energy of approximately 30 Mev., the initial ion-pair density in their tracks will thus be about 400 per micron and this will increase as the alpha-particles are slowed down. The remaining particles will be protons, deuterons and tritons, with initial ionization ranging from 30 to 100 ion pairs per micron. In all cases the average ionization density will be much higher.

The Lethal Effect of Ionizing Radiation

It is more or less certain that the lethal action of ionizing radiation upon living organisms arises as a result of chemical actions caused by the ionization which the radiations produce. Unless the radiation dose is really excessive, in which case the cells may be almost immediately destroyed, the effect of radiation is to produce changes in cells of living material, which lead to their death when they attempt division.

The death of the dividing cell may be due to changes in the genes or chromosomes. However, there is no evidence that gene mutations play a part in the death of organisms other than bacteria or viruses. On the other hand, the lethal effect in many plant tissues, such as broad bean root tips and *Tradescantia* pollen, appears to be due to chromosomal structural changes, which have been observed to take place. The chromosomes in the cells of human and animal tissues are difficult to study because of their small size. However, it is reasonable to assume that the same factors govern the destruction of these cells too.

The fact that lethal effects arise from chromosomal structural changes is important since the latter are very sensitive to the density of ionization along the tracks of the ionizing particles. Fig. 4 is derived from curves, given by Read[6], showing the dependence of the lethal effect on the broad bean root and the chromosomal structural changes in *Tradescantia* upon the track ionization density. The ordinate of this curve gives the *relative biological effectiveness* of radiations of a given track ionization density compared with that of single charged particles at minimum ionization (3 ion pairs per micron). For example, if the biological effectiveness at track density d is say 10, it means that a given

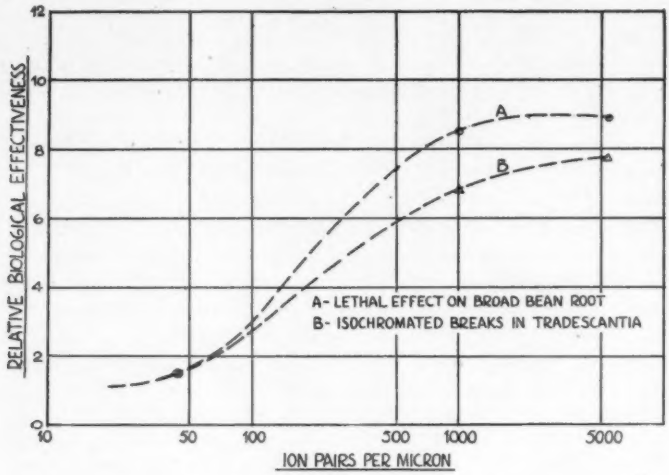

FIG. 4. Adapted from Read, *loc. cit.*

radiation dose of particles with track density d will produce the same effect as 10 times the dose of particles at minimum ionization.

It will be seen from these curves that there is a rapid increase in relative biological effectiveness between 100 and 1,000 ion pairs per micron. Below 100 the effectiveness is more or less one, for all densities, while above 1,000 it appears to reach a saturation value.

There are two main hypotheses for the action of the ionization. One (the "target hypothesis") assumes direct action, the ionizing particle passing through or very close to the structure affected and the ions producing chemical changes inside the structure. In the case of chromosome threads which are made up of long chain molecules, if a sufficient number of the chains are broken as a result of direct action of the ions, the thread will be broken. Lea[7] has deduced that about 20 ion pairs must be left inside *Tradescantia* chromatid thread (one tenth of a micron diameter) in order to provide a reasonable probability of a break. This corresponds to a linear ionization density of 200 ion pairs per micron. The increase in relative biological effectiveness in the range of track ionization densities between 100 and 1,000 is therefore explained, at least quantitatively, on the target hypothesis.

The hypothesis of indirect action depends upon the formation of active radicals in the water which makes up the bulk of living tissue.[8] It is well known that a large amount of chemical change can be produced in the solutes of dilute solutions by moderate doses of radiation. Thus dilute solutions of enzymes are largely inactivated by moderate doses of a few thousand r-units. Enzymes are present in cells in low concentration and their destruction might lead to marked effects.

The production of active radicals in water proceeds in the following manner.

The initial ion pair produces a positively charged water molecule and a free electron, which migrates a mean distance of about 15 millimicrons before being captured to form a negatively charged water molecule. The charged molecules then break up to form H and OH radicals.

Two possible situations may arise from the presence of these radicals in the solution. If the ion density along the track is small, then the mean separation of successive ion pairs is much greater than 15 millimicrons and the radicals react with the solute as a random mixture of H and OH. On the other hand, if the separation of ion pairs is substantially less than 15 millimicrons, the radicals are effectively distributed as a thread of OH radicles, along the track of the particles, surrounded by a mixture of OH radicals and H radicals. The high concentration of OH radicals along the particle track then favours the formation of hydrogen peroxide molecules. It is interesting to note that a mean separation of 15 millimicrons between successive ion pairs, corresponds to a pair density of about 70 per micron. At appreciably higher densities, we should expect the production of hydrogen peroxide to set in. Bonet-Maury and Lefort have shown that 0·27 molecules of H_2O_2 are produced per ion pair when alpha particles pass through water (Read *loc. cit.*) This is very close to the maximum production of 0·5 molecules per ion pair which is energetically possible. Thus it would appear that H_2O_2 production rises almost from zero to a saturation value for a range of ion-pair densities between 100 and 1,000 per micron. The fact that this is just the range over which the biological effectiveness shows a marked increase lends support to the possibility that it is the hydrogen peroxide which is the agency responsible for the breaking of the chromosomes and consequent cell destruction.

No matter which of the two hypotheses we may choose to use, the inference is the same, viz. that there should be a marked increase in biological effectiveness in the region of ion densities where, in fact, such changes have been observed in the organisms studied. There is no reason to suppose, on either hypothesis, that the effectiveness will increase indefinitely. On the contrary, we should assume that for densities greater than about 1,000, there would be no substantial further increase, but there might possibly be a fall due to wasted ionization.

The saturation value of relative biological effectiveness, appears to be about 10 in the case illustrated in Fig. 4. However, there is reason to believe that the value may be higher in lethal effects on animals. Thus Mitchell[9] reports a factor of 30 for the lethal irradiation of mice by neutrons over a 48 hour period. (Neutrons ionize via recoil protons of medium and low energy, c. 1,000 ion-pairs per micron.) This value is very close to that observed by Tobias, Weymouth and Wasserman in the lethal irradiation of mice by fission fragments, which ionize with a density initially greater than 100,000 per micron. Their value is 27, so that if one takes these two figures at face value, it lends support to the supposition that the relative biological effectiveness stays constant at ion densities greater than 1,000 pairs per micron.

The Effective Dosages Resulting from Exposures to Cosmic Rays

On the basis of the available information which we have given above, it would appear that a reasonable assessment of the effects of the various cosmic

ray primaries and secondaries can be made by assuming that for track densities less than 100 pairs per micron the relative biological effectiveness is unity; above 1,000 ion pairs per micron, it is 30 and between 100 and 1,000 ion pairs per micron, it increases linearly from 1 to 30 with the logarithm of the ion density. The relative biological effectiveness corresponding to different particles is then as follows:—

(*a*) *Primary and Knock-on Protons*; *primary helium nuclei*; *mesons and electrons.* Effectiveness 1.

(*b*) *C.N.O. primaries.* Effectiveness 10.

(*c*) *Heavier primaries.* Effectiveness 30.

(*d*) *Evaporation particles.* Half of these will be alpha particles with effectiveness 30, the remainder will be protons, deuterons and tritons with effectiveness in the range between 1 and 30. We will assume that about 100 Mev. (corresponding to about 3 million ion pairs) is dissipated by each star with a mean effectiveness of 20.

In estimating the effective dosage produced by each type of particle, we must first determine the ionization produced in a gram of tissue (1 cubic centimetre) by each. If we write F_p for the total current of particles of the given type p through each square centimetre, and if J_p is the ionization density expressed per centimetre of tissue, then the ionization dose rate D_p is simply given by:—

$$D_p = F_p.J_p \text{ ion pairs per gram per second}$$
$$= 3{\cdot}6 \times 10^{-7} F_p.J_p \text{ r-units per week.}$$

(In the case of primary protons, for example, $J_p = 10^4 j_{min.}$ i.e. 30,000 ion pairs per centimetre.)

The rate of star production due to the component p, will be given by S_p where:—

$$S_p = \frac{F_p}{l_p}$$

l_p being the given interaction mean free part for the component p. Each star will produce about 3,000,000 ion pairs due to evaporation particles. The contribution of the knock-on particles can be ignored, so far as ionization is concerned. However, as we have already indicated, they lead to an increase in the flux of minimum ionization particles and a consequent increase in the star rate "downstream." The dosage Ds_p due to these particular stars is then:

$$Ds_p = \frac{3 \times 10^6 F_p}{l_p} \text{ ion pairs per gram per second}$$

$$= \frac{1{\cdot}1\, F_p}{l_p} \qquad \text{r-units per week}$$

The ensuing table is based upon values of F_p deduced from Van Allen's data (*loc. cit.*) for a geomagnetic latitude of 41° N. The dosages apply to a small sample of tissue exposed above the atmosphere. It is assumed that tissue is essentially similar to air in producing evaporation stars (this is near

enough to the truth for our purpose). Thus the interaction mean free path, in centimetres of tissue, is taken to be the same as that in grams per centimetre² of air. The table includes the actual dosages calculated on the basis of the above expressions. The effective dosages, obtained by multiplying the actual dosages by the appropriate relative biological effectiveness, are given in the last column. Only the primary produced stars are included in this list, since the sample is assumed to be too small to allow any appreciable build-up of secondary particles.* Stars due to particles other than protons, or helium nuclei, have been ignored, because their frequency is relatively negligible.

TABLE III

Particle, etc.	F_p cm.²/sec.	J_p i.p./cm.	D_p r/week	D_{peff} r/week
Protons	0·37	30,000	0·0040	0·004
H Stars	0·37	l_p = 85 cm.	0·0035	0·070
Helium	0·09	120,000	0·0040	0·004
He Stars	0·09	l_p = 50 cm.	0·0020	0·040
C, N, O	0·003	1,500,000	0·0016	0·016
Na–Si	0·0006	4,500,000	0·0010	0·030
S, A, Ca	0·0002	10,000,000	0·0007	0·020
Fe	0·0001	20,000,000	0·0007	0·020
Total	0·46	—	0·0175	0·204

It will be observed that the effective dose rate is 0·20 r. This is sufficiently below the accepted tolerance dose to permit exposure of personnel for extended periods at this latitude. At the geomagnetic equator the dose rate is only a third and may certainly be neglected. On the other hand, at latitudes higher than 50–60° the dosage will be near to the tolerance value and cannot be ignored for long periods. Farther away from the Earth where the shielding effect of the Earth can be neglected, the dosage rate might even be expected to approach 2 or more tolerances and *some form of shielding would appear to be necessary, if exposures of the order of a year are contemplated.*

An interesting feature which arises from the assumptions which we have made in this paper is that the stars contribute slightly more than half of the effective dosage. Thus, if we move our sample down into the atmosphere, while we would decrease the dosage of heavy primaries, we should at the time increase the star rate dosage. As we have shown earlier, the star rate more than doubles as one penetrates through depths up to about 300 grams per square centimetre. We may predict, therefore, that the effective dosage rate would not be appreciably less at 25 kms. altitude, than above the atmosphere. This is contrary to Schaefer's conclusions, mainly for the reason that we have assessed the evaporation particles as being more or less equivalent to heavy primaries in so far as biological effectiveness is concerned.

The same remarks apply to any attempts to shield individuals inside space

* A man inside a space vehicle or high altitude aircraft is not, strictly speaking, a small sample. We will assume, however, that the effect of size and surrounding is not very great, the increase in star dosage roughly matching the decrease in heavy primary dosage.

vehicles. From the point of view of heavy primaries (carbon and beyond), a thickness of about 60 grams per square centimeter of a light material such as water or a plastic, would produce about a tenfold reduction in these primaries (assuming normal incidence—an even lower thickness would be required allowing for isotropic incidence). However, the increase in star production would almost certainly compensate for the reduction in primaries. The attentuation length of star producing primaries, once one is beyond the region of transitional increase, is about 140 grams per cm.^{2}, and the addition of say, this thickness of water will produce a reduction by a factor ϵ once we are beyond this zone. It would appear that at least 1 metre of water would be required to produce a worthwhile reduction. Obviously the weight handicap arising from a shield equivalent to a metre of water, would be excessive unless this represented useful material, such as propellants required at the end of the voyage.

Conclusions

The radiation hazard due to cosmic radiation is not likely to be serious for operations just above the atmosphere, even for fairly prolonged exposures. On the other hand, at great distances from the Earth the dosage may be well above the accepted tolerance level, and prolonged exposure may have adverse effects. Because a great deal of the effective dose comes from evaporation particles, the provision of shielding might introduce excessive weight handicaps unless this represents useful material. It must be emphasized that these conclusions are purely tentative, since they involve many assumptions (particularly as regards the relative biological effectiveness of the various particles). These assumptions require further experimental confirmation in the laboratory, and through further cosmic-ray observations.

Acknowledgement

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THE INSTRUMENTATION OF ROCKET MOTOR TEST BEDS

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(*A paper read to the Midlands Branch in Birmingham on February* 14, 1953.)

SUMMARY

The basic measurements required in rocket motor testing are stated. Methods of measuring pressure, temperature, flow rate and time are described with special reference to electronic techniques. The section on time measurement also deals with the firing of liquid propellant motors—some automatic systems are described. A final section briefly deals with auxiliary equipment required on a test bed, which is not directly concerned with measurement or firing.

Introduction

The four measurements required in rocket motor testing are pressure, temperature, flow rate, and time. If these quantities can be measured, all others can be obtained, e.g., thrust can be converted to pressure by means of a hydraulic or pneumatic ram, specific impulse is thrust divided by propellant through-put derived from flow rates, and so on. There are well established techniques for measuring all these quantities under normal conditions, but unfortunately conditions on a test bed are usually far from normal. A commercial type flowmeter for example would not last very long while measuring the flow rate of some of the oxidants in use to-day.

It might be said that the third quantity could be weight of propellants rather than flow rate if time is to be measured, e.g., if the weight of propellants before and after a run is known, the difference divided by the run time gives the flow rate. This is of course only an average value, however, and takes no account of such things as decreasing expulsion gas pressure causing varying fuel pump speeds, or eroding burner nozzles, thus making the value obtained of doubtful utility except in the early stages of design. A continuous measurement of the propellant weights would be better and for a large installation it is usually simpler (though not simple!) to measure flow rates directly. Accurate measurement of time is generally necessary for other reasons besides the estimation of through-put.

Pressure

Pressure is by far the most essential quantity to be measured in motor design Fig. 1 shows the points in a propulsion system where measurements may be taken and it will be seen that pressure measurement may be required at many more points than any other quantity. Combustion chamber pressure, thrust and through-put measurements will give most of the information necessary for performance estimation.

The most commonly used instrument for pressure measurement is the Bourdon gauge. Though robust and easy to read, it has some severe disadvantages. If a permanent record is required of its readings, it must be photographed. This may limit its effective frequency response to a period

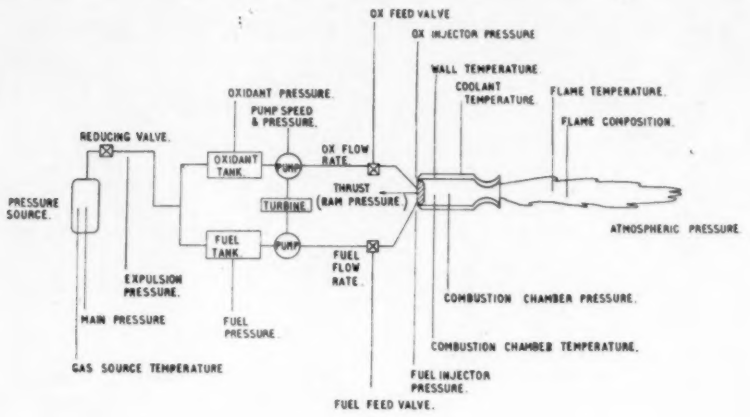

FIG. 1.

of one or two seconds—possibly 10 per cent. of the total run time. Strictly speaking the Bourdon tube itself will respond to rapid fluctuations, but surging in the lines feeding it, fluid damping in those lines, and the mechanical inertia of the movement, render its readings suspect, and, of course, the cine camera used for photography may have a very limited frequency response (300 frames per second is a very good speed to attain, but an expensive one). The latter difficulty may be overcome by fitting Bourdon gauges with small precision potentiometers instead of pointers and recording the voltage output on high speed pen recorders. Frequency responses of a few hundred cycles per second may be obtained in conjunction with mirror galvanometers. An alternative, the mechanical recorder, so-called to differentiate it from electric or electronic recording systems, uses spring-loaded piston elements and linkages to give a linear movement to stylus pens pressing against a clockwork- or electrically-driven roll of paper. A governed gramophone type clockwork motor actuates a timing stylus and frequencies up to 30 c/s may be recorded.

For recording the pressures of high temperature gases and corrosive liquids, the lines feeding Bourdon and piston type gauges must be primed with some inert fluid such as carbon tetrachloride, and it will be appreciated that the longer such lines are, the lower will be the frequency response obtained. Great care must be taken to avoid getting air locks in the lines when priming, otherwise readings will be too low. With care, a panel of Bourdon gauges can give much information, and used in conjunction with a camera taking pictures every one or two seconds, will give all the information required about most of the pressure points shown on the figure. Those points where a gauge is inadequate are those where rapid pressure changes occur, i.e., the combustion chamber, the thrust pressure ram, and points in the propellant lines after the fluid feed valves where the rate of pressure build up at the injectors may be required. At these points transient pressure changes corresponding to a

frequency of several thousand cycles (kilocycles) per second may be encountered, especially on delayed ignition or "hard starts." In such cases, providing that the measuring equipment or even the test bed has survived, the peak pressures recorded may depend entirely on the transient response of the equipment.

The high frequency limit in a pressure recording system may occur either in the pressure sensing or pick-up element or in the recording system. For example, a photographed gauge panel will probably be limited in frequency response by the speed of the cine camera used—on a mechanical recorder the limitation is in the stylus linkages aggravated by damping in the priming lines. The first stage in designing a high speed recording system is therefore to reduce the inertia of all moving elements and to endeavour to have the pressure-sensing element in such a position that it may be actuated directly by the pressure source. The best way to reduce inertia in the recording system is to replace the pointers, pens, styli, etc., by the electron beam of a cathode ray tube.

This beam, to all intents and purposes, is inertialess—speeds of movement up to 4 in. per millionth of a second (micro-second) are readily attained, the limitations generally occurring in the associated circuitry. As an everyday example, the spot of light on the flourescent screen of a television receiver, produced by the electron beam of the C.R.T., moves from left to right in about 90 micro-seconds and back again in about 10 micro-seconds. This latter corresponds roughly to a frequency of 100 kc/s. In order to record this movement we must focus the spot on to a continuous strip of film moving past in a direction perpendicular to the spot's motion, at such a speed that the individual fluctuations in time are separated in space on the film. This is analogous to providing a time base deflection on the tube, and in fact an electronic time base may be provided on the recording tubes for test purposes. At very high speeds of film the spot never illuminates any given part of the emulsion for very long, i.e., the exposure time is very short, and very sensitive film and very bright spots must be used. This means that the recording cathode ray tubes must be run at high voltage, producing very small and intense spots, and if these are allowed to remain stationary for any length of time, the fluorescent screen material will be destroyed by the electronic bombardment at the point of rest and a permanent dark mark will result. This can be avoided by deflecting the beam away from the screen by electrostatic or magnetic means, only bringing it back to the normal start position a fraction of a second before the recording run begins.

A good high-speed continuous film camera will run at about 200 inches per second—corresponding to a frequency response of 5 kc/s if the trace width be about 1mm. This can be increased by using a drum camera in which the film is wound round a large diameter drum spinning at high speed. Several revolutions of the drum can be used for recording by raising it by means of a screw gear thus producing a helical trace, but even so run times are very short. A film speed of 2,000 inches per second may be obtained corresponding to a frequency response of 50 kc/s. Thinner traces will reproduce higher frequencies. Having obtained our high speed recording device, we must now consider means of converting the pressure we wish to measure into the voltage

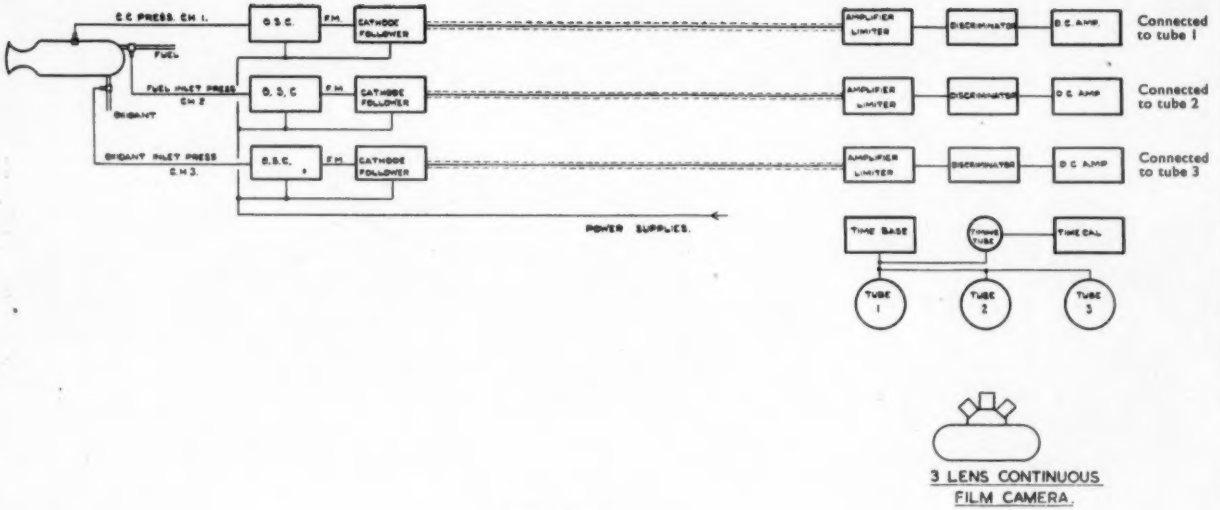

FIG. 2A.
Three Channel F. M. System
(*See Fig.* 2B *on page* 218.)

required to deflect the cathode ray beam. This may have a value of 200 to 1,000 volts for an electrostatically deflected tube, depending on the E.H.T. potential (i.e., the voltage used to accelerate the electrons in the beam). A normal oscilloscope tube running at 2,000 volts E.H.T. will require about 300 volts to move the spot fully across the screen (say 10 cms.). If the E.H.T. was increased to 6,000 volts in order to produce a more intense spot for high speed recording, the deflecting voltage would have to be increased to 900 volts. The amplifiers used to produce these deflection voltages must have a linear response from zero frequency (i.e., D.C.) to the top frequency required. All methods of pressure recording involve the use of some type of pick-up which directly or indirectly produces a voltage more or less proportional to the pressure being measured. This voltage is amplified until it is sufficient to deflect the beam the required amount—full scale deflection corresponding to the maximum pressure expected. This deflection may not necessarily be directly proportional to the pressure. For example, the normal running pressure may be 600 p.s.i. but may rise to 1,800 p.s.i. in transients or under certain conditions of malfunction. To reproduce this latter pressure on a linear system would mean running at low sensitivity under normal conditions—a non-linear characteristic such that (say) 1,000 p.s.i. give 0·8 of full scale, where full scale required 2,000 p.s.i., would be preferable, provided that calibration was easy and rapid. Since the long term stability from the point of view of zero drift is poor in most systems, it is generally axiomatic that calibration of the system be performed daily, if not before and after every run. This calibration is generally done with a dead weight tester, the spot deflection for each increment and decrement of pressure being recorded on the film which is to, or has, recorded the run. A dead-weight tester is a device which produces pressure, usually in a hydraulic system, by loading a piston with known weights; thus the weight used divided by the cross-sectional area of the piston gives the pressure imparted to the system.

The two main systems of pressure recording which can themselves be subdivided into sub-systems are the frequency modulation (Fig. 2) and bridge (Fig. 3) systems. In the F.M. system, the pressure is made to vary the reactance of a component in the frequency controlling element of a medium frequency (e.g., 2 mc/s) oscillator. (The component may be the inductance or capacitance of a tuned circuit or a resistance or capacitance in a phase shift or bridge type resistance capacitance oscillator.) In one type the pick-up consists of a steel disc spaced a few thousandths of an inch away from another rigid metal surface by means of an insulation ring. This forms a low capacity two plate condenser. If pressure be applied to the disc either directly or through the compression of some material such as petroleum jelly, the disc is deformed, the gap alters, and so does the capacity. The thickness of the disc is chosen to give a certain capacity change for the pressure range to be covered. One range has a capacity of 200 picofarads (200×10^{-12} farads) with a change of 30 picofarads for pressure of 0–100 to 0–1,600 p.s.i. The pick-up is connected across the tuned circuit of an oscillator working at one or two million cycles per second (mc/s). The latter is mounted flexibly in a water-proof box fixed as closely as may be convenient to the pressure points

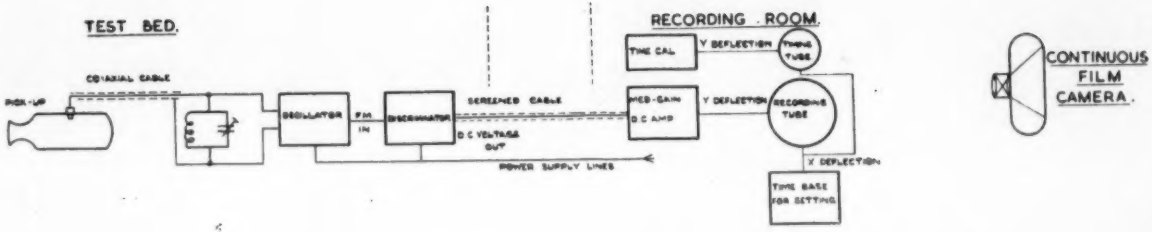

FIG. 2B. Single Channel Remote Discriminator. F. M. System.

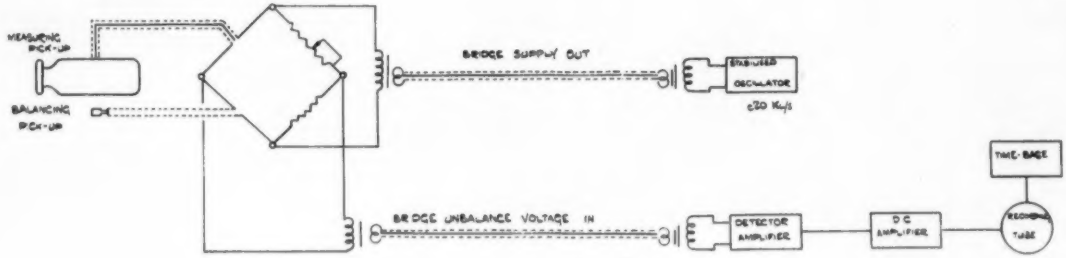

FIG. 3. Single Channel Bridge System.

required. Since the cable connecting the pick-up to the oscillator has capacity which may reduce the available tuning range, a compromise must be struck between liability of the equipment to damage, possible variations in cable capacity producing spurious signals, acoustic excitation of valves in the equipment, etc. The oscillator output is fed to a discriminator, which is a circuit giving (within certain limits) an output voltage directly proportional to the input frequency deviation about a centre frequency. This discriminator may be mounted either with the oscillator or remote from it in the recording room (see Fig. 2A and B). The voltage output from the discriminator—which is proportional to the frequency deviation and, therefore, to the pressure change—is amplified and used to deflect the recording tube spot. Two or three channels are generally used in this system, each with its own oscillator, discriminator and recording tube. It will be seen that, up to the discriminator, the system measures frequency changes only. Variations in oscillator amplitude caused by microphonic valves, cable and plug vibration, variable cable losses, voltage or hum pick-up, etc., will not affect the readings. The voltage output of the discriminator is usually large enough to mask any noise pick-up on the lines back to the recording room if the discriminator is in the test bed. It has been found, however, that vibration of discriminator components can cause spurious voltage outputs, and it is rather better to "pipe back" the oscillator output, though this may require extra amplifiers or cathode followers to overcome the line losses or to match their low impedance. A line is "matched" when the source feeding it (usually known as the "generator") has the same impedance as the line and the latter has the same impedance as the load it is feeding. This produces optimum transfer of power and no reflections producing standing waves on the line. Impedance is a complex quantity analogous to the resistance opposing the flow of current in a D.C. system. A centre frequency of 2 mc/s with a frequency deviation of $\pm$ 20 kc/s will give a good linear characteristic. The upper frequency limit of the pick-ups is generally greater than 10 kc/s.

One major source of error in this system is that caused by the heating of the pick-ups. An increase in temperature during a run may cause the disc to expand and the capacity to alter as much as 10 per cent. of the change due to pressure rise. It has been found necessary to water-cool combustion chamber pressure pick-ups. Pick-ups should be checked daily to ensure that large pressure surges have not stressed the discs beyond their elastic limit, causing serious changes in sensitivity. Corrosion of the discs may also prove serious.

The other main system, the bridge system, is almost self-explanatory. The pick-up element, which may be of the same type as that used in F.M. systems, is made one element of a Wheatstone Bridge excited by A.C. of high audio frequency, 20–25 kc/s. The bridge is balanced by variable resistors against a dummy pick-up—either an actual pick-up to which no pressure is applied, or a small robust variable condenser. Change of pick-up capacity will then unbalance the bridge and produce a small A.C. output which is amplified, rectified, the resultant D.C. amplified again, and used to deflect the recording tube spot. (See Fig. 3.)

An advantage of this system is that the dummy pick-up can be exposed

to all the conditions of the true pick-up, except the pressure change, thus balancing out all changes due to temperature rise, noise pick-up on the bridge, input, etc. The main disadvantages are as follows:—

(*a*) The bridge output is small so that pick-up on the lines back to the detector amplifier may be serious.

(*b*) The bridge is frequency sensitive as reactances are balanced against resistances. This might be avoided or reduced by an all capacity bridge, though inductance effects might be appreciable.

(*c*) This frequency sensitivity means that the bridge supply oscillator must be very frequency stable and care must be taken to avoid false nulls due to balancing unwanted reactive components.

(*d*) The output amplitude of the supply oscillator must be stabilized, a change in amplitude causing the bridge sensitivity to alter.

A resistance-capacitance oscillator with thermistor or feedback amplitude control is generally used. This system gives many channels with comparatively simple equipment—the test bed end consisting merely of pick-ups and balancing resistors—perhaps remotely controlled. Another type of pressure pick-up which can be used on a bridge system or perhaps on an F.M. system with a relaxation oscillator, is the carbon resistor pick-up. If a carbon composition resistor be subjected to compression by immersing it in a liquid, or semi-solid, to which pressure is applied, the resistance of the composition changes in a linear manner with the pressure. Thus a carbon resistor pick-up may consist of an ordinary carbon composition resistor with any protective coating removed, packed in petroleum jelly behind a light diaphragm. Pressure applied to the diaphragm is communicated as a compression to the resistor by the jelly. The resistor is made one arm of a Wheatstone Bridge or used as a frequency controlling element in a resistance—capacitance oscillator. High stability type resistors must be used and temperature changes must be avoided or balanced out as indicated above. Frequency responses of several kilocycles per second may be obtained.

Temperature

For general temperature measurements on rocket motor test beds, thermocouples are almost universally used, the type depending on the temperature range to be covered, since the changes to be observed are not generally rapid The output of the couple is generally connected to an ordinary galvanometer which is then photographed. In some cases it is sufficient merely to note its readings at certain stages. For heat transfer work a thick copper combustion chamber may be used, with small thermo-couples sunk into its walls at various depths. A panel of galvanometers usually of the "edge on" type (to save space) is photographed by a cine camera, and the distribution and rise of temperature is easily observed. A disadvantage is that the couples tend to interfere with the heat flow through the metal. In motor design and development the chief measurement is that of coolant outlet temperature. Auxiliary equipment, such as cordite gas generators, may, however, require many temperature measuring points.

The measurement of the high temperatures existing in combustion

chambers (1,000°–2,500° C.) and exhaust flames (1,000° C.) presents special difficulties; for example, combustion chamber temperature measurements may require a quartz window in the chamber wall, which limits the duration of run.

Thermocouples may be used if made of high melting point metals with high resistance to chemical action. Such metals as platinum, rhodium and palladium are suitable and may be used but these are very expensive! A couple made of platinum and platinum-rhodium alloy can be used up to 1,800° C. Thermocouples cannot be used in a high velocity gas stream, due to adiabatic heating at the obstruction, and possible chemical or catalytic action may be caused by the metals of the couple. This limitation also applies to the heated wire method where a wire is heated in the flame. With a platinum wire the upper temperature limit is about 1,800° C.

Optical pyrometers may be used where there is a reasonable time to take a measurement. The most common type, the disappearing filament, uses a tungsten lamp, the filament temperature of which is known by calibration against the current flowing through it. The current is adjusted until the image of the filament viewed against a background of the flame or hot body being measured just disappears. A monochromatic filter is used to minimize colour differences between the source and the lamp. The rated maximum temperature of the lamp is generally about 1,600° C. Since combustion chamber observations are generally made through a small quartz window or at an angle into the venturi, black-body conditions approximately prevail and the pyrometer will give the true brightness temperature of the surface observed. For flame temperature measurements, the flame must be made luminous, possibly by the addition of carbon particles. The luminosity then depends on the flame thickness and only steady state conditions may be observed. This latter difficulty may be overcome by the use of photo-electric cells. Since it is easier to measure relative intensities rather than absolute intensities, the following method may be used. The ratio of intensity of emission of two wavelengths by a black body is a function of temperature, thus if the intensity of radiation at (say) red and blue can be measured, the temperature of the body can be calculated. Corrections can be made for non-black-body conditions. Thus, if the radiation from a source be applied to two photoelectric cells fitted with red and blue filters, a continuous record of the outputs can be taken and the ratio at any instant calculated. With this method, there is, theoretically, no upper temperature limit. (Using a carbon arc as the calibrating source, suitably corrected for non-black-body conditions, temperatures up to 2,500° C. can be measured.)

The method is not applicable if a non-continuous spectrum is being emitted. However, small amounts of other substances can be added to make the flame a continuous emitter. Cathode ray recording techniques may be used to record very rapid temperature fluctuations. The optical pyrometer or photo-cell methods are not applicable to non-luminous flames and rocket motor exhausts are—or should be—non-luminous. If sodium chloride be added to the flame, the sodium lines in the spectrum emitted would have an intensity corresponding to the flame temperature. If the flame spectrum were observed

superimposed on the background of a continuous spectrum obtained from a known temperature source such as a calibrated tungsten lamp, at the point where source and flame temperatures were equal the sodium lines would change from being brighter than the background spectrum to weaker. This is known as the line reversal method. Here again, the thickness of the flame can affect the result and the outer layers of the flame may have a greater effect than the inner if they are of different temperatures. If the temperature of the comparison source can be changed rapidly, or its emission varied by means of a moving neutral wedge filter, fairly rapid measurements can be taken using a spectograph recorder.

For other reasons, it may be desirable to examine the flame spectrum, thus examination of the structure of the bands emitted may lead to an estimation of the temperature. Finally, rough estimation of temperature at certain points in a propulsion system may be obtained by the use of certain paints which change colour at high temperature. Again fusible alloys may be used to give approximate results, generally to give an indication of overheating in certain components.

Flow Rate

While measurement of the rate of flow of liquid is fairly easily carried out by means of commercially available equipment under normal conditions, in rocket motor test work the corrosive nature of some of the propellants and the high pressures to which they are subjected make the problem much less easy of solution. Rotameter type instruments can rarely be used with such fluids, mainly because such instruments require direct observation and component parts must be oxidant-resistant. Instruments used should be remote reading, as the measuring elements must be placed in the fluid feeds and are therefore in the "danger area." Owing to sealing difficulties there should be no physical connection between the element affected by the fluid flow and the element which detects and transmits the effect, preferably as some electrical change. One method in use has a polythene encased iron dust core, of the type used in radio inductors, attached to a piston which is moved by the flow. The dust core moves inside a sealed polythene tube, round which is wound the tuning coil of a small oscillator. Both the frequency and the amplitude of the oscillator output will change with the piston movement. Either of these changes can be detected and used to deflect an ordinary moving coil meter mounted at some point convenient for observation or photography.

Another method uses a revolution counting technique. The liquid, the flow of which is to be measured, is caused to flow round a disc-shaped chamber so that a stainless steel ball-bearing is carried round and round the periphery. The chamber itself is made of non-magnetic material but has an electromagnet winding attached in such a manner that there is a large change in magnetic flux through the coil at every revolution of the ball. The resulting current pulses are converted to voltage, amplified, and used to operate a cycle counter or frequency meter. The rate of revolution of the ball and therefore the output frequency is a measure of the flow rate round the chamber. A small vane spinning in the flow through a straight pipe can also be used to

generate electric pulses by means of which its rate of revolution may be measured. Rotating devices generally have a long line constant due to their momentum. The piston type, however, will detect transient surges lasting as little as 0·1 seconds. An up-to-the-minute method might be to introduce a small amount of radioactive material into the propellants and then to measure the radioactivity by means of a geiger counter at the point in the system where measurements were required. The rate of count would be proportional to the amount of fluid flowing past that point in a given time, although calibration of the system might present some difficulties.

Time

The measurement of time is probably the easiest task required of an instrumentation engineer. The duration of test runs may be measured by means of the observers' stop-watches, and timing marks generated by clock-work mechanism may be added to film or paper records. For electrical timing, the 50 c/s mains frequency may be conveniently used, especially if a frequency meter is available; in these days of load-shedding it is necessary to note its reading during the run. Timing marks or "pips" may be generated by valve circuit frequency dividing or counting techniques. A typical piece of timing gear might be built up as follows. A squaring circuit and pulse generator are used to obtain short pulses at mains frequency—50 c/s. These pulses are used to trigger a phantastron circuit which divides this frequency by five and produces larger pulses at 10 c/s. This frequency is divided by ten to produce still larger pulses at 1 c/s. All these pulses are added together to generate a "ruler" type timing pulse train, the timing pips being 1 sec., 1/10 sec. and 1/50 sec. apart. These pulses are used to deflect the spot in a small cathode ray tube photographed simultaneously with the recording tubes. The lower frequency pulses can also be used to deflect auxiliary timing pens on paper recorders. If greater accuracy or higher speed timing is required a crystal oscillator or tuning fork may be used as the basic frequency standard followed by the usual counting or dividing stages. As far as the layman is concerned, a phantastron is a "black box" which will divide the frequency of its output pulses by any integral number between 2 and 20.

Though not strictly concerned with time measurement, it is felt that motor firing equipment may be dealt with here as the accurate timing of various operations in a firing sequence is one of the main reasons for the complexity of the equipment sometimes used. It is perfectly feasible to fire a motor by means of a switch panel, the switches operating the various equipments or services directly. The times of the various operations may vary widely from firing to firing and in some cases the very small interval of time in which a certain operation must be performed may cause misfires or loss of information from recording gear. For example, if high speed recording cameras are used, it is very desirable to reduce the interval between the camera starting and the motor being fired to a minimum. Many tens of feet of film can be wasted in a few seconds, and unless the interval is exactly known, all this blank film must be developed and examined in order not to miss the start. An automatic firing system will not only switch on all auxiliary equipment in the correct

order and at the right times, but also start and time the run itself, stop the run and switch off all equipment, and can more easily be incorporated into a safety interlock system.

A typical system might be constructed to operate as follows. "Pressurization," "Start Sequence" or "Fire" and "Emergency Stop" switches are provided at the control point. After pressurization has been effected (the time for which may vary widely), the "Start Sequence" or "Fire" switch brings into play a clockwork or telephone exchange type selector switch. This operates in turn, at a controllable rate, a bank of relays which themselves switch power to the auxiliary equipments and main test bed services. At some chosen point in the sequence, the ignitor is fired and finally the main fluid feed valves are opened. As this starts the run proper, the same relay also starts a clock which is set to time the run. After the preset running time is completed a second selector comes into action, unless emergency stop action has been taken. This second selector stops the motor and switches off auxiliaries at the required intervals. It may also initiate water spray or fire supression devices. Safety interlocks may be incorporated, so that the sequence will be stopped and the test bed made safe if the emergency stop switch be operated. The system may be so set up that the sequence is stopped and reset to "Safe" in the event of power supply failure or of careless mishandling of the controls, e.g., pressing two buttons at once. A "consequential" sequence can be used, i.e., one in which the operation of any relay is consequential on the operation of the one before it in the sequence. For maximum flexibility, the equipment or "service" relays are connected to the selectors by multiway distributors, so that any order of sequence can be adopted and any number of relays can be operated at one time—for example, it may be necessary to operate several solenoid valves at the same instant.

Besides ensuring that faulty operation of the equipment cannot cause a misfire, it is essential that firing (or in fact any dangerous operation) can only be done by the proper person, and from the proper place. The first is generally ensured by the use of a "safety link." This may be a short piece of cable with a suitably keyed plug at each end. These plugs fit into sockets on the control panel and when they are out, both sides of the power supply to all possibly dangerous services are broken—in fact, it is generally the practice to make all equipment on the test bed electrically dead when the safety link is out. The link is generally carried by the safety officer and only given to the firing officer when the test bed has been cleared and checked as safe for firing. It is obviously a very undesirable state of affairs if the safety links have to be inserted to test any piece of gear and it is essential to ensure that newly added pieces of test equipment on the test bed, which may derive their power directly, do not cause bridging of either side of the safety link connection, especially on the earthed or earthy side.

It is often desirable to test automatic firing system before firing and a "Test Start" condition should be available. By means of this the relay equipment can be checked on non-safe supplies, i.e., supplies not routed through the safety link, without operation of test bed gear. It should also be arranged that the "Fire" switch will only operate the equipment when the safety links

are in and the system set up in the firing condition. The object to be aimed at is that only a would-be suicide can fire the equipment and then only from a place of safety!

Miscellaneous Equipment

As eye-witness accounts of phenomena lasting for very short periods of time are notoriously unreliable, it is usually mandatory to have photographs of a test run in order to obtain a permanent record of any information which can be gained by observation, such as the appearance of the flame. This camera can be either a cine camera or an automatic aircraft camera taking pictures every few seconds. These can be operated manually but, since they are generally placed in situations which would be decidedly unhealthy for human observers, they are more generally stopped and started electrically. The automatic type may be controlled by push button from the control point, by timing pulses from the firing equipment, or by both means. The camera should be protected as much as possible from the consequences of an explosion and can often be sited so as to photograph a gauge panel and clock as well as the motor.

For firings of very large motors where conditions dictate very remote observation, a television relay system might be useful—the firing officer being given a close-up view of the device he is attempting to control, while being adequately protected. A camera record is very useful for showing what did happen, but it is sometimes possible to make what did happen much less spectacular—and less expensive—by the control office being able to see what *is* happening. An almost essential item of the test bed equipment is a loud speaking multiway intercommunication system so that all parts of the test bed are in direct and rapid communication with each other at all times. This greatly facilitates the setting up of remote reading equipment and the relaying of firing instructions. Last, but not least, one should have a fire engine and ambulance on standby during attempted firings. Rocket motors do sometimes explode, whatever their designers may say to the contrary, and the rapid delivery of a large quantity of cold water in the right places can prevent much damage, material, personal and economic.

BRANCH MEETINGS

Midlands Film Show, April 18, 1953

The meeting was intended to take the form of two film shows at 3.0 p.m. and 6.30 p.m., respectively, but unfortunately no electrical power was available during the afternoon and the 3.0 p.m. show had therefore to be postponed until May 16.

Three films were screened at the 6.30 p.m. show—*The German A.4 Rocket*, which described the construction and operational firing procedure of this rocket, *High Altitude Research*, a short film which described briefly how the space in the nose of rockets fired by the U.S. Army Ordnance Corps was utilized to carry instruments for high altitude research. It included shots

from a camera mounted in one of these rockets which rose to a height of 70 miles. The film was in colour. The third film was untitled and dealt with recent experiments in which two mice and a monkey were fired up to a height of 38 miles in an *Aerobee* rocket. The film showed the mice undergoing "free fall" conditions and was of particular interest. As it was silent it was accompanied by a commentary given by the Branch Secretary.

107 members and visitors were present at this meeting.

Midlands Branch Exhibition

At the invitation of the Birmingham and Midland Institute Scientific Society, the Midlands Branch entered an exhibit in the Annual Conversazione of the above Institute, held on the evenings of January 13–16, 1953, in Birmingham.

The Conversazione is described as a festival of the Arts and Sciences and is one of the social events of the year, attended, as it is, by the Lord Mayor and Lady Mayoress of Birmingham.

The theme of the Branch exhibit was an attempt to show some part of the past and present of rocketry and its possible future use for interplanetary flight.

Representing the past were models of a "Propulsor" and a later-type Goddard rocket.

Models showing present-day applications were made to the same scale and included a Rheinbote complete with launching vehicle, a V2, Viking, and a V2-WAC Corporal (Bumper Project).

As an indication of future possibilities, there were two impressions of the shape spaceships may take, one of these being a two-step model. Also in this section was a one-seventeenth scale impression of a life compartment of a Lunar spaceship, containing movable control panels complete with television screens and wander plugs for circuit checking, acceleration couches which could be converted into chairs by operating a handwheel and which were mounted on rails so that they could slide outwards when the ship was rotated to provide artificial gravity, and also a combined telescope and coelostat. This model aroused a great deal of interest among visitors, and B.I.S. members on duty were kept very busy explaining the uses and operations of the various components.

Suspended above the exhibit was a small scale model of a space station with a Type A ferry rocket in attendance.

As a background to the exhibit, the wall behind the stand was hung with photographs of rockets and rocket firings, a large pictorial chart showing the position of the various zones between the Earth's surface and an altitude of 1,000 miles and indicating the heights attained by balloons, aircraft, rockets, etc., and finally, a collection of paintings showing impressions of planetary surfaces.

Two further models were on show, one being an illuminated cut-out showing the basic layout of a bi-propellant rocket motor, and the other a steam-powered rocket motor producing thrust against a counter-weight. By holding a metal plate in the jet of steam from the exhaust, the thrust was reduced and the motor fell back under the influence of the counterweight. This latter model was used in an attempt to prove to visitors that a rocket does not need to push against anything to produce forward motion.

A view of the Midlands Branch exhibits.

Completing the exhibit were several photographs of the Moon, showing some of its interesting surface features, and coloured diagrams of rocket motor layouts. Photographs and reports of the exhibit appeared in the local press.

Acknowledgements

The Birmingham and Midland Institute Scientific Society for their kind invitation to exhibit and the facilities provided.

The Editor of *Aeronautics* for the rocket layout diagrams.

Mr. Eric Burgess for the Lunar photographs.

Mr. N. R. Nicoll for the model life compartment.

Mr. W. J. Baker for the rocket models.

Mr. D. A. Hardy for the wall chart and paintings.

Midlands Branch Committee Members for their help and support in constructing the exhibit and their attendance during the exhibition, and particularly Mr. R. B. Beard, who also contributed several rocket models.

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Informal Yorkshire Branch

A meeting of the Branch was held in Leeds on April 25, 1953, when Mr. G. Hollis read a paper entitled "Life on other Worlds."

Mr. Hollis began by discussing the conditions under which life could survive on Earth and mentioned that living organisms are found in Siberia and near the Poles, where extremely low temperatures are encountered, besides in the depths of the oceans where the pressure is many times more than atmospheric. The living cycle on earth involves a combination of oxygen with carbon and a synthesis of carbohydrates into living matter.

The possibility of other chemical reactions taking the place of the carbon/oxygen cycle was discussed. In particular, the replacement of carbon by SiO was mentioned and a cycle based on ammonia or methane was postulated. The temperature and pressure ranges required for the various possible systems were also mentioned.

Mr. Hollis then considered conditions on the planets and the likelihood that some form of life might have appeared elsewhere in the solar system, and mentioned various theories on the formation of the planets, to see if conditions might have existed in the past which would allow life to develop. He concluded by saying that there was a strong probability that elsewhere in the Universe, life of a similar nature to our own existed. Eventually, perhaps, we might come into contact with other intelligent creatures, though our own system seemed unlikely to contain any but ourselves.

38 members and visitors were present.

Provisional Western Group

The Spring programme of the Western Group consisted of two lectures and a film show, held at the Folk House, College Green, Bristol.

On February 7, 1953, Mr. R. K. Taylor presented a paper entitled "An Introduction to the Rocket Motor."

Mr. Taylor described the main components and general arrangement of a typical rocket motor and the talk, which was amply illustrated with slides, enabled the host of difficulties which confront the rocket engineer to be fully appreciated.

28 members and visitors were present.

On March 7, 1953, Mr. W. R. Clark addressed the Group on the subject of "The Planets."

The talk was a general introduction to the solar system, and was followed by a lively discussion.

29 members and visitors were present.

The film show on April 11, 1953, was very well attended, the following films being screened:—*Faster than Sound, Rocket Instrumentation, The German A.4 Rocket.*

As all have been fully reviewed in the previous issues of the *Journal*, details are not being given here.

34 members and visitors were present.

"BRAINS TRUST"

As Mr. R. A. Smith was unable to lecture to the North-Western Branch on March 21, 1953, his lecture, "The Establishment of the Lunar Base" will be presented next session.

To avoid disappointment to those members who attended, a "Brains Trust" was arranged at very short notice, the "Brains" being E. Burgess, A. C. Clarke, C. A. Cross and Dr. L. R. Shepherd. The following is a shortened account of the proceedings.

Q. Is there a factual basis for the drawing of the multiple sun in the Chairman's book "The Exploration of Space"?

A. C. CLARKE: The drawing is based on current views of astronomers, but I have cheated a little by including the components of two real systems. The large "red giant" and its "white dwarf" companion are modelled on ζ Aurigae. The outer layers of the red star are so tenuous that the companion actually shines through them in the first stages of its eclipse.

The weird dumbell shaped object is a visualisation of β Lyrae. This is also seen from the Earth as an eclipsing binary; i.e., the Earth is in the plane of the spiral. The complex structure is deduced from the periodic changes in light intensity and the shifts in spectral lines as the object revolves. There is also a slow increase in the period of rotation.

C. A. CROSS: The artist has, perhaps, given the spiral undue emphasis. All the evidence is indirect, because the stars are too far from us to appear as anything but points of light.

Q. How soon does the team think the first artificial satellite will be established, and what will it be used for?

A. C. CLARKE: I expect there will be a small automatic satellite within twenty-five years. It will probably be used to transmit instrument readings back to Earth.

DR. L. R. SHEPHERD: The most likely use will be the collection of cosmic ray data, but we can also expect spectroscopic data from the sun and planets as an early development.

E. BURGESS: The time taken will depend on the political situation to a very large extent, war might set the project back disastrously.

C. A. CROSS: The first satellite may well not have any real use at all—it may be merely the shell of a small rocket, the final step of some two or three step-sounding rockets in some preliminary experiment just to see if it could be done.

Q. What would be the cost of development of an artificial satellite?

DR. L. R. SHEPHERD: This would depend almost entirely on to what extent it was a matter of urgency. Doing it in a rush could cause a similar position to that which arose over the first atomic bomb, where several separate lines of development were worked out simultaneously, because there was not time to see which was the best, or even if any of them would work at all. In

similar circumstances the cost of an artificial satellite might well be comparable with that of the atomic bomb.

A more moderate speed of development would avoid all this waste, as much of the work would be done free in allied fields and the bill would then be much reduced. However, no one should place too much reliance on this sort of calculation. It is too dependent on the costing system used, and possibly on the accountants who are using it!

Q. What is really holding up the interplanetary project?

A. C. CLARKE: The public—and particularly the American public—has been "oversold" on interplanetary travel by publications which emphasize the spectacular possibilities and minimize the unsolved problems.

E. BURGESS: The development of a really efficient rocket motor operating with high energy propellants still remains the chief obstacle.

C. A. CROSS: A really compelling reason is needed—of the kind that would make nations willing to spend manpower and material resources on these problems.

DR. L. R. SHEPHERD: A great deal of work must be done in almost every conceivable branch of science, and the amount of ground-work to be covered is immense.

Q. Can the team explain the time paradox that has recently been discussed in the "Journal"?

DR. L. R. SHEPHERD: The so-called time paradox arises from the fact that, according to the special relativity theory, there is a change in the time scale between observers in relative motion. Thus the tempo of events in a space ship moving at a velocity near to that of light, would appear, to an observer at rest on the earth, to be slowed down to an extent dependent on the relative speed. The paradox occurs because the motion is purely relative and it should be equally true that events on the earth should appear to the space traveller to be slow on his time scale. The matter can only be fully resolved on the basis of the general theory of relativity, taking into account the acceleration of the ship. However, the true state of affairs can be understood from the Fitzgerald contraction, according to which, the distance between the stars appears reduced along the line of motion, to the voyager in the ship and journey is made more quickly as a result. To the earth-bound observer, however, it is only the ship that appears foreshortened and the journey time appears normal.

That the effect is not merely imaginary, is demonstrated by observations on mesons, which are produced when cosmic-ray primaries enter our atmosphere. The average lifetime of these unstable mesons is far too short to allow them to reach the surface were it not for the relativistic time dilatation.

Q. What variations are likely in the orbit of a satellite vehicle?

E. BURGESS: The orbit is affected by the Moon, the Sun, the Earth's equatorial bulge, and by the other planets. The changes which result can be calculated from the method of perturbations.

These calculations show that if the period of rotation is an integral fraction of the Moon's, serious changes will result. The precession of the nodes due to the action of the Earth's bulge may also be troublesome but all the other factors are of much less importance than these. In every case very small corrective actions would suffice to maintain the orbit.

NOTES AND NEWS

Nominations for Council, 1953/4

In accordance with the provisions of Article 15 of the Society's Constitution, one-third (i.e. *four*) Members of the Council will retire from office at the Eighth Annual General Meeting, which will be held on Saturday, December 5, 1953, at the Kent Room of Caxton Hall, London, S.W.1, commencing at 6 p.m.

Nominations are invited from members for election to the Council for next session.

Signed nominations should be forwarded to the Secretary as soon as possible, and in any event, not later than October 24, 1953.

Back copies of Publications

A number of back issues of *Journals*, *Annual Reports*, etc., are now available for purchase by members.

Complete volumes for some previous years may be obtained at a cost of £1 5s. 0d. per volume, while many individual issues of the *Journal* (including several pre-war copies) are available at 3s. 6d. each and copies of *Annual Reports* at 4s. 0d. each.

A small number of copies of foreign Society publications are also available, e.g., *Weltraumfahrt* at 2s. 0d. per copy, and copies of the *Journal of the American Rocket Society* at 4s. 0d. per copy.

Sets of astronautical postcards are also available price 2s. 0d. per set of six.

Orders and inquiries should be addressed to the Secretary at 12, Bessborough Gardens, S.W.1.

South African Interplanetary Society

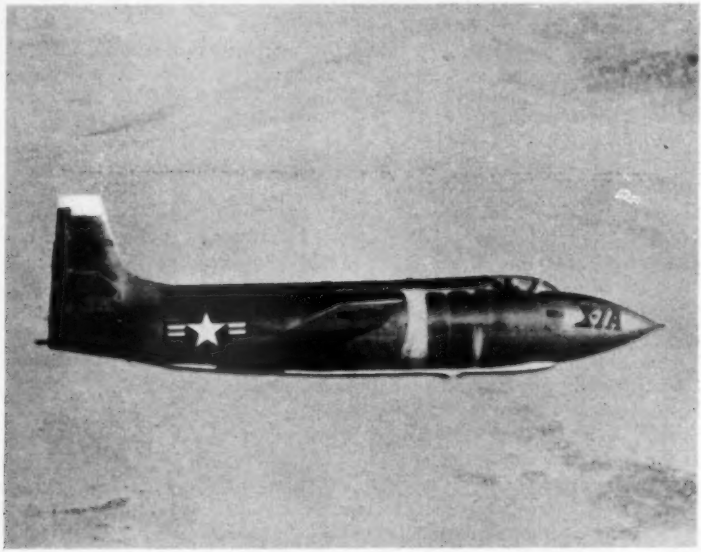
The inaugural meeting of the South African Interplanetary Society was held in Johannesburg, 1953, when the President, Professor A. E. H. Bleksley gave an address.

We should like to extend a cordial welcome to this new Society, which has been incorporated under the South African Companies Act, and which will shortly be applying for membership of the I.A.F.

Glasgow Meeting

Our Chairman, Mr. A. C. Clarke, will deliver the inaugural lecture of the David Elder Series at the Royal Technical College, George Street, Glasgow, on October 21, 1953, at 7.45 p.m.

His subject will be "The Exploration of Space" and will deal with the evolution of the space flight idea and how recent developments have brought astronautics from the realm of fantasy to a subject for serious consideration.



Rocket-powered Bell X-1A is shown in its first flight over Edwards Air Force Base, U.S.A.

Standing left to right: J. Geertsma, J. H. Houtman, Dr. J. J. Raimond Jr., M. J. Bottema (secretary, Study Group), J. v. d. Vliet, A Lopes Cardozo (member, Study Group), J. de Groot (secretary, N.v.R.).

The Secretary-General of the Royal Technical College informs us that admission tickets are available, price 1s. 0d. each.

Bell X-IA

The Bell X–IA is one of a series of aircraft designed specifically for supersonic flight, and bears a strong family resemblance to the original Bell XS–I which in 1947 first exceeded Mach 1·0 in level flight. However, whereas the XS–I employed a gas pressurized propellant feed, the new aircraft embodies a turbo-pump. The power unit for both variants, built by Reaction Motors, Inc., consists of four separate motors each delivering 1,500 lbs. thrust; these may be used separately or in multiples to realize the maximum thrust of 6,000 lbs.

The X–IA is slightly larger than the original XS–I; it can be distinguished by the raised cockpit canopy, the fairing of which continues back to the vertical fin. The original machine has a flush cockpit canopy.

A Boeing B–29 Superfortress is employed to carry the research plane to an altitude of 35,000 ft., where it is released in a similar manner to a bomb. The motor is then lit and the aircraft is made to climb rapidly to the test altitude. The research plane is carried partially within the bomb-bay of the Superfortress which has been specially modified to receive it.

A further development is the Bell X–2, the second example of which is nearing completion. This is a swept-wing aircraft having a stainless-steel wing and a nickel-alloy fuselage; it is expected to reach Mach 2·0. The first X–2 was lost after an explosion which occurred in the bomb-bay of the Superfortress.

Mr. Clarke's Lectures in Holland

The photograph reproduced opposite was taken on the occasion of our Chairman's visit to the Hague, at the invitation of the *Nederlandse Vereniging voor Ruimtevaart* on March 14, 1953.

Seated on Mr. Clarke's left is Dr. J. M. J. Kooy, President of the N.v.R. and co-author of "Ballistics of the Future." Standing, left to right, are J. Geertsma, J. H. Houtman, Dr. J. J. Raimond (vice-president, N.v.R.), M. J. Bottema, J. v. d. Vliet, A. Lopes Cardozo, and J. de Groot (secretary, N.v.R.).

During his three-day visit, Mr. Clarke met many reporters, spoke on Hilversum radio, and lectured to the N.v.R. at the Park Hotel, Den Haag. He was very hospitably entertained by the N.v.R. and was given a conducted tour of Delft, Rotterdam and Amsterdam by Dr. Kooy.

Rocket Experiments with Mammals

The *Journal of Aviation Medicine*, **23**, 421–432, Oct. 52 contains full details of the recent rocket experiments in an article entitled "The Animal Studies of the Subgravity State During Rocket Flight."

Three Aerobees were used for this study, the entire noses of the second and third rockets being fitted with instruments for specific physiological studies.

Scientific equipment being installed in the Warhead of a V-2 Rocket in one of the early experiments at White Sands Proving Ground, 1946.

The nose sections were equipped with parachutes, as it was hoped to recover both the instruments and the animals by this method.

As there was no satisfactory parachute recovery of Aerobee I modifications were introduced into Aerobee 2, and, with minor adjustments, was used with success in Aerobee 3. In Aerobee 1 satisfactory data was received up to the point of impact.

Two types of study were undertaken:

(*a*) Physiological information either of pulse and respiratory rhythm or of arterial and central venous pressure on seven anaesthetized Rhesus, Cebus, or Cynomolgos monkeys.

(*b*) The second type of study was on five mice and made by indirect photography. In Aerobee 2, the behaviour of a normal mouse was contrasted with that of a Labyrinthinectomized mouse (i.e., an electrocautery needle had been applied to the horizontal semi-circular canals in the membranous labyrinth of the middle ear).

The experiment using the anaesthetized monkeys was the first attempt at telemetering direct physiological data from high altitudes, and for this credit must be given to the engineers concerned.

Tables of pulse, respiration and electrocardiograms obtained from the anaesthetized monkeys showed remarkable evidence of freedom from disturbance.

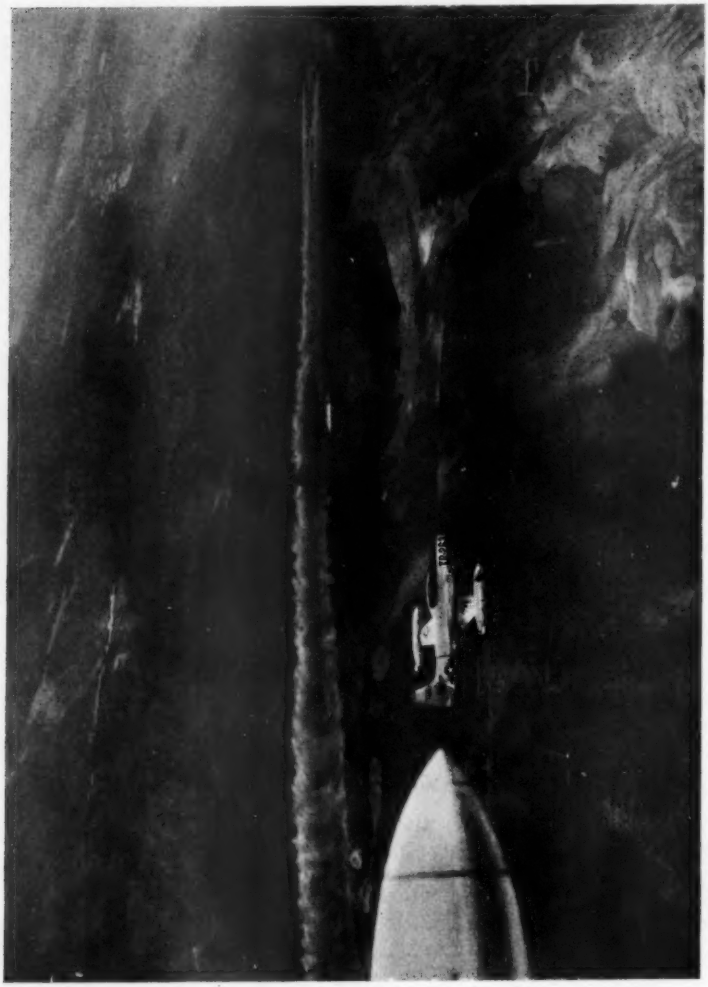
The cardiovascular system upheld the predictions that properly secured animals would not experience significant disturbances during the power of ascent and the period of gravity-free state.

There was an increase of temperature by 15° C. in the nose of the rocket, due to skin friction and thermal solar radiations at high altitudes. A slow fall in both the systolic and diastolic arterial pressure was observed during the subgravity phase of the Aerobee 2. This may be significant, as it may represent adaptation of the cardiovascular to the subgravity conditions, during which conditions the hydrostatic pressures are virtually eliminated. This suggestion is supported by the fact that there was a slight upward trend of the blood pressure following the parachute opening and on the return to I*g*. Further evidence of this is required, as the changes of temperature may have had an effect causing the blood pressure fluctuations.

The mice were exposed to subgravity conditions in very different circumstances, i.e., they were able to rely on their visual and tactile senses for orientation as they clung to the walls of the cage or to the paddle. The photographic records of the mice were made through 2 to 3 minute periods of subgravity. Providing a foothold was available to the animals they appeared to be disturbed only to a minor extent. In all cases they behaved normally following the resumption of an orienting gravity stress.

Evidence suggests that in attainable durations of 2 to 3 minutes the subgravity state will not lead to any major psychophysiological difficulties.

The development of the orbital rocket must be awaited before the effects of subgravity lasting for many hours can be investigated.



Lockheed F-94C Starfire interceptor firing rockets.

From the World's Press

Press reports at the beginning of May gave news of a field-day at Woomera which was attended by Anglo-American VIP's and by Mr. Menzies, the Australian Prime Minister. Mr. Menzies himself pressed the button to launch the small remote-controlled jet plane known as Jindivik (Firebird), which successfully carried out manoeuvres under the guidance of an accompanying Meteor. Developed by Ian Fleming, who was trained at Cambridge and Sydney Universities, the Jindivik has a British Armstrong Siddeley Adder jet engine but otherwise has been built entirely in Australia. It is said to be intended for use as a target for weapons which will be tested at Woomera, whilst a number may be sold to the United States as "game" for their robot supersonic rocket missile, the Nike. According to the May reports, 12 Jindiviks have been tested at Woomera and 54 more have been ordered. It is also stated that since 1950, 700 rockets and 440 other missiles have been launched at Woomera, and 2,200 bombs have been dropped.

During his visit, Mr. Menzies was shown a rocket-engined model demonstrating the Fairey vertical-take-off plane, first trials of which were made during 1949 from a ship off the Welsh coast. With its two booster rockets included, this machine is said to develop a thrust of 3,000 lb.

Mr. Menzies also witnessed a successful firing of the 600 lb., 1,000 m.p.h. R.T.V.1, which is a true rocket. Says the *Daily Mail* of May 4, "It is not the prototype of any particular missile, but is what its name implies—a 'vehicle' for basic tests of aerodynamic and other conditions applicable to bombs still under development."

* * * *

This last remark brings to mind a statement by Dr. Meyer-Cords, of the G.f.W. which was reported in the newspapers of May 18. Here Dr. Meyer-Cords is credited with saying that America is building a spacestation.

This is progress indeed! Only last year a story originated in Germany that an artificial satellite was circling the Earth—this year one is being built. Next year, progress being sustained, it will no doubt be back in the drawing office, along with its biological counterparts the chicken and the egg.

In fairness to Dr. Meyer-Cords, we should, however, point out that though he apparently *did* say "I know at least 1,000 men are working on this station," he probably did *not* say that it was actually *being built*, as headlines of the *Nottingham Guardian* make out. Nor we think did he say (as the same paper and the *Irish Times* had it) that 1,000 men were working *in* the station.

* * * *

As everyone knows, the critical moment in the life of a spaceship is the instant of launching, when it either goes up or blows up. Thereafter, in the case of a real ship, nobody except the crew really cares what happens. After all, far more people want to build the darn things than want to fly them, and in a democracy the majority count.

At least that is true of experimental trips—when fare-paying passengers are concerned, as with the Scarborough ship, one has to be rather more careful.

It is not yet known whether naming the ship *Anastasia* and having it christened by a charming actress, such as Miss Frances Day, will prevent accidents, but as there is a lamp standard directly in the line of flight of the Scarborough vessel and it has not yet crashed, there is some reason to think that such precautions are effective. On the other hand, the presence of a member of the B.I.S. at the naming ceremony in St. Nicholas Gardens may have put the ship in a good humour before "Dan Dare" and "Digby" took over the controls.

Be that as it may, there is no doubt whatever that the *Anastasia* was successfully launched. Indeed, so far as publicity goes the Scarborough ship has secured a practically unassailable lead over its two sister-ships of London and Blackpool, all of which have been ingeniously designed by Messrs. Pictorial Displays. Apart from numerous write-ups in various northern papers, there have been newsreel and B.B.C. recordings, and a local song-writer-organist, Leslie Sturdy, has written a catchy little number about it, which has been sung by an audience at the Futurist cinema.

* * * *

The following amusing piece, *Trip to the Moon*, by the A.P. newsfeature writer Arthur Edson, is reprinted without comment . . . . We daren't!

Washington, May 11—(A.P.)—The trouble with most of us, Mrs. Walton C. John says, is that we don't have vision. We don't realize that in twenty-five years, maybe less, we'll whisk off to the moon in a rocket.

Mrs. John thinks she is the only American woman who is a member of the British Interplanetary Society. She is certain she is the only one to join an interplanetary group because an enthusiastic eighty-year-old urged her to do so.

The enthusiastic eighty-year-old was her mother.

"Mother," Mrs. John said to-day, "had vision."

Mother—Mrs. Anna L. Colcord, who died three years ago—urged so strenuously Mrs. John couldn't say no.

"I didn't see the point at the time," she said, "but I'm certainly glad I did. It helps to look ahead. I have found it's just like a medicine."

The head medicine man of the British Interplanetary Society, Arthur C. Clarke, was in these parts last week. Naturally he checked up on his only American woman member, and made this little prediction for her:

Man will reach the moon by 1978.

Mrs. John thinks Clarke, like so many Englishmen, tends to be a mite conservative. "Look at predictions in the past," she said. "Twenty-five years often have turned out to be five."

Clarke thinks we earthlings shouldn't try for a non-stop trip to the moon. He'd like to set up a man-made planet, or space station beyond the earth's atmosphere.

"That would be 1,075 miles up." Mrs. John said, "We could use it as a jumping off point."

Mrs. John thinks the space station will be wonderful for astronomers.

"The atmosphere distorts everything seen through a telescope," she said. "The space station will give us a chance to see things as they really are."

Mrs. John has no college degrees, but her husband was with the U.S. Office of Education until his death eleven years ago. So she's used to moving among people who have a lot of theories.

"Someone has said, 'Agitation of thought is the beginning of wisdom.' I feel it helps to keep our thoughts agitated," Mrs. John said.

"Anyway, we need new frontiers. The world is getting too small."

Mrs. John said she was surprised to be talking with me. That's because she phoned our office here a couple of years ago, and—

"I explained to the man who answered the phone all about our interplanetary plans. When I had finished, I asked him, 'Now isn't that interesting?' "

"The man didn't say anything at all for a couple of minutes. Then finally he said, 'No.' "

That's the trouble with most of us all right, Mrs. John. Not enough vision.

* * * *

A Washington press release of February 20 announced the world's first space suit. Developed by the United States Navy for use by high-altitude fliers, the dress is completely self-contained and automatic in operation. Pictures and descriptions reveal that the suit is made of rubber with corrugated limb joints for flexibility. There is a domed Plexiglass helmet, and strongly reinforced boots and gloves are provided. No technical information is given, and no mention is made of duration, but it is stated that if anything happened to the aircraft's pressure system the pilot would be able to continue his mission. It is claimed by the Navy that the user has almost complete mobility, but the U.S. Air Force is reported as saying that it abandoned research along the same lines some time ago because suits of this type were so cumbersome that the wearer could not move properly .... We do not wish to become embroiled in the argument but must say we are in favour of being alive and stiff rather than dead and stiff.

* * * *

A use for rockets which has hitherto been overlooked (or suppressed) is contained in a letter to the Editor of the *Sheffield Telegraph* of March 31, from which we print the following extract:—

"Sir,—It is now known that the flood damage was due to high tides plus strong gales. Had there been no high tides, the gales would not have broken down the sea defences. The obvious remedy is to do away with tides. Not so fantastic as it might seem!

Tides are caused by the attraction of the moon dragging the sea round the whirling earth. Abolish the moon and we shall get rid of these troublesome tidal waves.

Now the British Interplanetary Society assures us that we could land a rocket on the moon *now*, if the Government would furnish the money. All technical details have been worked out.

In the head of this rocket, timed to detonate on impact, could be placed one or more atomic or hydrogen bombs. As the moon is a dried up world, and has long been subjected to alternate doses of fierce heat and terrible cold it must be very brittle and full of cracks and caves.

The explosion of the bombs would probably shatter it into a cloud of dust and fragments drifting along the moon's orbit.

We should lose the romance of Luna, but shipping would be much easier. No waiting for the tide! And as an illuminant for the night the moon is a wretched failure."

An automatically inflated extreme-altitude tracking balloon, such as may ultimately be used in space itself, and which was in fact foreshadowed in the B.I.S. *Journal* article *Orbital Bases* (Jan., 1949), has now been developed by the Goodyear Tire and Rubber Company.

According to the *India Rubber World* (N.Y.) of March and *Science News Letter* (Washington) of February 28, the balloon has a wall 0·015-in. thick consisting of two-ply nylon fabric processed with a nylon coating. The balloon is installed in the nose of an Aerobee rocket, the cone portion of which is blasted free electronically when the missile is at the peak of its flight. This action automatically releases the sphere, which is then inflated by means of a pressurized cylinder contained within itself. The device, thus carried to heights previously quite inaccessible to balloons, will be used for studies of high-altitude weather and long-range communication.

* * * *

The *Japan News* of Tokyo, dated March 13, quotes Dr. H. C. Urey, 1934 Nobel Prize winner for his discovery of heavy hydrogen, as telling newsmen that he believes intelligent beings exist elsewhere in the universe. Pointing out that astronomers estimate that there are some one million million million solar systems besides our own, Dr. Urey went on to say: "It would be preposterous to think that there was not life in some intelligent form in some of these."

It is interesting to note that Tennyson believed this long before the existence of extra-terrestrial beings was generally admitted as a probability, for in *The Two Voices* we find these lines:—

> Think you this mould of hopes and fears
> Could find no statelier than his peers
> In yonder hundred million spheres?

Milton of course went even further, as is apparent from this truly astronautical question posed in *Paradise Lost*, where the poet asks:—

> In which of all these shining orbs hath man
> His fixed seat, or fixed seat hath none,
> But all these shining orbs his choice to dwell.

* * * *

Under the headline "The Ramps are Trained on Europe on the Red Rocket Coast," Antony Terry, writing in the *Aberdeen Press and Journal* of May 26, gives an account of Soviet rocket bases along the 500-mile East German coastline from Stettin to Luebeck. Says Terry: "Along this coast the Russians are believed to have massed giant atomic-warlike rockets which could destroy Europe in a night." It is claimed that the account is based on a factual assessment built up from agents' reports and cross-checked refugee stories. The principal points of interest are collated below, though the B.I.S. does not vouch for the accuracy of the information!

"Reports so far describe the Russians' V bases as each containing four groups of eighteen rocket projectors capable of firing the 'S 8'—a Soviet development of the Nazis' V2 which is stated to have a range of 2,600 miles . . . ."

"The actual projectors from which the 'S 8' is launched are tubes 20 ft. in diameter. They are suspended in a larger underground gallery, 40 ft. across and nearly 200 ft. long and are capable of being 'swung' a few degrees to right or left for aiming. They point west, south-west and south—towards Britain, West Germany, France and the Mediterranean area . . . ."

"Each gallery and its projectile slope upwards towards the mouth. Thus when the rocket leaves the gallery and emerges above the earth, it is roughly at the right angle to rise for its flight . . . ."

"The actual firing mechanism which simultaneously fires the rocket and opens the doors of the base for a split second to allow the projectile to escape is nearly 200 ft. underground . . . ."

"With six of these eighteen-rocket bases already built, or nearly completed" (they are said to be invisible from the air) "the Soviets therefore already dispose of a rocket 'artillery' of over 430 projectors in the Rostock area alone."

Terry goes on to tell of an even more advanced weapon, the "S 14," sites for which are said to be located under the sea in the area west of the island of Ruegen. It seems that the firing tubes for these missiles can be swung 20° to left or right, but no other details are given.

* * * *

A B.U.P. report in late April says that U.S. weather experts claim to have stimulated rainfall by firing rockets loaded with silver iodide into storm clouds at between 11,000 and 13,000 ft. The trials were made off Saint Barbara, California, a steady downpour following twenty minutes after the rockets exploded.

* * * *

U.S. Television Service

Some months ago the Johns Hopkins University asked the viewers of its half-hour television programme, "The Johns Hopkins Science Review," what sort of programme they would prefer to see during the six weeks from July 12 until August 16, 1953.

The response from the viewers, which was announced on the programme for July 5, was overwhelming and almost unanimous for a series of programmes on "Man's Conquest of Space."

The programme appears over the C.B.S. Television network.

"Hah! Get this character—
'Bang, bang, you're dead!' "

Reproduced by courtesy of the Editor of Collier's.

* * * *

Acknowledgement

The Council wish to acknowledge with grateful thanks the receipt of a painting of a rocket against a lunar background, kindly presented by Mr. J. A. Branson.

ABSTRACTS

Edited by J. HUMPHRIES

Abbreviations of titles of journals were given in the May, 1950, issue of the *Journal*, and addenda have appeared in subsequent issues. The following is a further addendum to the list:—

Ann. Fac. Econ. Comm. Univ. Bari.	Annali Facoltà Econonomia e Commercio di Universio di Bari.
Aust. Engr.	Australasian Engineer.
Boll. Geod. Sci. Aff.	Bolletino Geodesia e Scienze Affini.

Many of the articles noted are available on loan to members resident in the British Isles. Requests should be addressed to J. Humphries, 97, Churchill Avenue, Southcourt, Aylesbury, Bucks.

AIRCRAFT

See also abs. no. 239.

(202) **Thoughts on rockets and aircraft.** A. V. CLEAVER. *Aircraft*, **30**, 16–19, 46 (*Aug.* 1952).

(203) **Supersonic X-IA begins test.** *Aviation Wk.*, **58** (14) 18 (*April* 6, 1953).

ASTRONAUTICS

See also abs. 213 and 214.

(204) **Astronautics: new science of space travel.** M. GOLDSMITH. *Aust. Engr.*, 72 (*May*, 1952).

(205) **Third International Astronautical Congress.** P. GALLINA. *Boll. Geod. Sci Aff.*, **11**, 461–464 (*Oct.-Nov.-Dec.*, 1952). (*In Italian.*)

(206) **Final report of the *Ad Hoc* Space Flight Committee of the American Rocket Society.** *J. Amer. Rocket Soc.*, **23**, 103–104 (*March-April*, 1953). Recommendation that space-flight should be a major aim of the A.R.S.

(207) **Relativistic rocket theory.** W. L. BADE. *Amer. J. Phys.*, **21**, 310–312 (*April*, 1953). General solution of one-dimensional rocket motion in field-free space.

(208) **The practical side of space-flight.** M. W. ROSEN. *Machine Design*, **25**, 284, 289–290, 293, 296, 298, 300 (*May*, 1953). Lecture given at Hayden Planetarium Symposium. [See also *J.B.I.S.*, **12**, 26–32 (*Jan.*, 1953).]

ASTRONOMY

(209) **The physical theory of meteors. III. Astroballistic heat transfer.** R. N. THOMAS and F. L. WHIPPLE. *Astrophys. J.*, **114**, 448–465 (*Nov.*, 1951).

(210) **The rocket and the future of astronomy.** A. C. CLARKE. *Hunting Group Review*, 4–8 (*Winter*, 1952). Survey of fundamental principles and high altitude research.

(211) **Ecological aspects of planetary atmospheres with special reference to Mars.** H. STRUGHOLD. *J. Aviation Medicine*, **23**, 130–140 (*April*, 1952). Considers that only Mars and, possibly, Venus, have ecological spaces suitable for active life. Discusses minimum oxygen requirements and suggests that plants could provide "internal atmospheres" on Mars. (50 *refs.*)

(212) **On the possibility of obtaining radar echoes from the sun and planets.** F. J. KERR. *Proc. Inst. Radio Engrs.*, **40**, 660–666 (*June*, 1952). The process of reflection from the sun is investigated theoretically, together with the manner in which the echo intensity would depend on the parameters of a radar system. Orders of magnitude of planetary echoes are also briefly discussed. (14 refs.)

ATMOSPHERE

(213) **Where does space begin?** H. STRUGHOLD, *et al.* *J. Aviation Medicine*, **22**, 342 (1951).

BIOLOGY AND MEDICINE

See also abs. 211 and 222.

(214) **Physiological problems of life on board artificial satellites.** P. BERGERET. *Médecine Aeronautique*, **6**, 249–252 (1951). (*In French.*)

(215) **Human experiments in subgravity and prolonged acceleration.** E. R. BALLINGER. *CADO Techn. Data Dig.*, **17**, 10–12 (*May*, 1952).

(216) **Physics and psychophysics of weightlessness—visual perception.** S. J. GERATHEWOHL. *J. Aviation Medicine*, **23**, 373–395 (*Aug.*, 1952). Discussion of the effect of gravity on vision. There is no experimental work at zero g but it is thought that sensory illusions may occur, especially as gravity changes from normal to zero. (69 *refs.*)

(217) **Bailout at very high altitudes.** F. HABER. *J. Aviation Medicine*, **23**, 322–329 (*Aug.*, 1952). Considers conditions at M = 10 and altitudes up to 300,000 ft. At such altitudes there is no problem as deceleration = 0·1 g only. A peak of 6 g is reached due to free fall from 300,000 ft.

(218) **Exposure hazards from cosmic radiation beyond the stratosphere and in free space.** H. J. SCHAEFER. *J. Aviation Medicine*, **23**, 334–344, 401 (*Aug.*, 1952). Due to possible danger from heavy nuclei rays it is not possible to assess the danger. Danger may lie in the extremely high specific ionizations of the heavy primaries. (16 *refs.*)

(219) **Radiation hazards in high altitude aviation.** C. A. TOBIAS. *J. Aviation Medicine*, **23**, 345–372 (*Aug.*, 1952). Confined to a discussion of dosimetry and a survey of the expected biological effects with special reference to actual flying conditions expected in the near future. (70 *refs.*).

MATERIALS

(220) **The formation of refractory coatings by vapor-deposition methods.** C. F. POWELL, I. E. CAMPBELL and B. W. GONSER. *Project Rand. Rept.* R–137, 97 pp. (*March* 25, 1949.)

PHYSICS

See also abs. 209 and 247.

(221) **Thermodynamic constants of gases at high temperatures.** M. G. RIBAUD. *Pub. Sci. & Tech. du Min. de l'Air Rept. No.* 266. Introduction deals with modern theories of specific heats and calculation of thermodynamic constants of gases. The tables relate to the molecules and atoms most frequently met in practice.

(222) **The diurnal intensity variation of the heavy primaries of cosmic radiation and its consequences for the hazard to health in flight at extreme altitudes.** *J. Aviation Medicine*, **22**, 351 (1951).

(223) **Thermal properties of fluorine compounds: heat capacity, entropy, heat content and free energy functions of diatomic fluorine in the ideal gaseous state.** L. HAAR and C. W. BECKETT. *Dept. Comm. Nat. Bur. Stand.*, 16 pp. (*Feb.* 1, 1952).

(224) **Comment on "An approximate theory of porous, sweat, or film cooling with reactive fluids," by L. Crocco.** A. E. ABRAMSON. *J. Amer. Rocket Soc.*, **23**, 97 (*March-April*, 1953).

(225) **Design of apparatus for determining heat transfer and frictional pressure of nitric acid flowing through a heated tube.** B. A. REESE and R. W. GRAHAM. *N.A.C.A. RM* 52D03, 61 pp. (*June* 16, 1952). (18 *refs.*)

(226) **In the ocean of rays from the sun.** K. WIESE. *Nat. u. Tech.*, **7**, 106–108 (*April*, 1953). (*In German.*) Shortened version of paper delivered at 3rd International Astronautical Congress.

PROJECTILES

See also abs. 207 and 237.

(227) **Current problems in guided missile engineering.** H. M. COBB. *Photogr. Engng.*, **3**, 119–120 (1952).

(228) **Optical attitude recorder for the Aerobee rocket.** G. SCHWEISINGER. *Photogr. Engng.*, **3**, 169–177 (1952). Description of device which records reliably the sun, a watch dial and the horizon whenever it appears in the 150° field of one or more of three auxiliary wide-angle systems. A single camera is used to superimpose these three wide-angle fields in different colours on 16 mm. film in such a way that a later optical separation is possible.

(229) **Tracking the bird.** *Flying*, **50**, 9 (*April*, 1952).

(230) **Disturbances of rocket flight by wind action and similar influences.** H. HÖSLI. *Flug. u. Tech.*, **14**, 177–183 (*Aug.*, 1952). (*In German.*) Deals with effect of cross-wind on the trajectories of ground-fired rockets, and of cross-wind and side-slip on rockets fired from aircraft. Results presented in graphical form.

(231) **The impact of guided missiles on ground warfare.** N. A. PARSON. *Military Review*, **32**, 16–22 (*Aug.*, 1952).

(232 **On the method of taking into account the flattening of the earth in the motion of missiles.** A. GENNARO. *Boll. Geod. Sci. Aff.*, **11**, 413–424 (*Oct.-Nov.-Dec.*, 1952). (*In Italian.*) It is shown that it is sufficient to suppose the mass of the earth to be concentrated at one point, whose position is a function of the projectiles initial position.

(233) **Guided missiles: science fiction or fearsome fact?** L. N. RIDENOUR. *Ryan Reporter*, **13**, 10–12, 29 (*Dec.* 1, 1952). Brief developmental survey.

(234) **Two ballistics problems of future transportation.** W. A. ALLEN. *Amer. J. Phys.*, **21**, 83–89 (*Feb.*, 1953). Considers the problems of travelling along a great circle and of travelling radially out from the earth, both with constant acceleration.

(235) **Gyro bearings ride on air.** *Machinist*, **97**, 291–292 (*Feb.* 21, 1953). Describes air bearings developed for guided missile gyroscopes.

(236) **Missile program still lags dangerously.** D. A. ANDERTON. *Aviation Wk.*, **58**, (9), 83–85, 87–88, 91–93, 95 (*March* 2, 1953). Comprehensive review of American guided missile progress.

RADIO AND ELECTRONICS

See also abs. 212.

(237) **Cathode ray recorders for missile application.** C. H. SCHLESMAN. *Photogr. Engng.*, **3**, 78–88 (*Feb.*, 1952). Comparison between telemetering, magnetic tape and photographic recording.

ROCKET MOTORS

(238) **Rocket applications.** *Chemical Week.*, 15 (*Jan.* 26, 1952).

(239) **Republic tanker fuels rocket interceptors.** *Aviation Age*, **17**, (4), 9 (*April*, 1952). Tanker for liquid oxygen, alcohol and nitrogen.

(240) **The Sprite rocket motor.** *Aviation Age*, **17**, (4), 36–37 (*April*, 1952). Detailed description.

(241) **Experimental rocket motor performance with white fuming nitric acid and JP-3 at 700 and 300 p.s.i.a. combustion pressure.** C. M. BEIGHLEY and D. E. ROBISON. *Purdue Univ. Rept. RL/R–1–52–2*, 19 pp. (*May*, 1952.)

(242) **Explosive liquid aviation motors, rockets and the turbo-prop groups.** M. BOUFFART. *Chal. & Ind.*, **33**, 299–312 (*Sept.*, 1952). (*In French*). Principles of rocket propulsion, combustion chambers and general construction.

(243) **Combustion instability in liquid-fuel rockets.** R. S. LEVINE and R. B. LOWHEAD *Aviation Age*, **19**, 50–55 (*Jan.*, 1953). Discusses four classes of instability.

(244) **Momentum thrust of a rocket.** R. K. SHERBURNE and W. L. WEEKS. *Amer. J. Phys.*, **21**, 139–140 (*Feb.*, 1953). Derivation of the momentum thrust equation directly from classical mechanics.

(245) **Typical problems in the design of liquid propellant rockets.** V. SIVORI. *Aerotecnica*, **33**, 118–122 (*Feb.*, 15, 1953). (*In Italian.*) Examination of choice of propellant and mixture ratio, design of chamber together with heat transfer problems, choice of feed system and weight analysis and aerodynamic problems of installations in missiles.

(246) **Combustion studies in rocket motors.** K. BERMAN and S. H. CHENEY. *J. Amer. Rocket Soc.*, **23**, 89–96, 98 (*March-April*, 1953). An investigation of combustion instability with 3 in. diam., 1,200 lb. thrust motors using a slit-window. Pictures of shock propagation axially along the motor are presented.

(247) **Stability and control of liquid propellant rocket systems.** Y. C. LEE, M. R. GORE and C. C. ROSS. *J. Amer. Rocket Soc.*, **23**, 75–81 (*March-April*, 1953). It is shown that the problem may be investigated with respect to system dynamics, combustion time lag and interaction of the two. Stability criteria are established for a gas-pressurized bipropellant system and the pump-feed system is also discussed.

(248) **Servo-stabilization of low-frequency oscillations in a liquid bipropellant rocket motor.** F. E. MARBLE and D. W. COX. *J. Amer. Rocket Soc.*, **23**, 63–74, 81 (*March-April*, 1953). It is shown that by use of a feedback system containing a device to sense the combustion chamber pressure, a suitably designed amplifier, and a servo-mechanism which governs the propellant flow, the low-frequency oscillations which occur in the rocket configuration may be stabilized for any value of combustion time lag.

(249) **Rocket engine design advances.** *Aviation Wk.*, **58** (15), 47 (*April* 13, 1953). Details of North American Aviation liquid-propellant rocket motor for test sled. Sled can accelerate from rest to Mach 2 in 5 secs. The thrust is 50,000 lb. and cost per firing $100 compared with $5,000 for equivalent solid propellant unit.

ROCKET PROPELLANTS

See also abs. 241.

(250) **Method of determination of the characteristics of propellant mixtures for rockets.** G. NEBBIA. *Ann. Fac. Econ. Comm. Univ. Bari*, **10** (1950). (*In Italian.*) Method of calculation of specific impulse, combustion temperature, etc. Results plotted for nitric acid and aniline. (13 *refs.*)

(251) **Peroxide rocket propellant.** *Aviation Age*, **17** (4), 35 (*April*, 1952). Refuelling trailer for D.H. Sprite.

(252) **Fluoroscope tests rocket propellants.** *CADO Techn. Data Dig.*, **17**, 13 (*May*, 1952).

(253) **How one base meets problems of handling rocket fuels.** *CADO Techn. Data Dig.*, **17**, 3–5 (*May*, 1952).

(254) **The velocity of sound in some rocket propellant liquids.** G. G. KRETSCHMAR. *J. Amer. Rocket Soc.*, **23**, 82–84 (*March-April*, 1953). By use of an ultrasonic interferometer data were obtained for nitric acid, hydrazine, J.P.3 and J.P.4.

(255) **On maximum evaporation rates of liquid droplets in rocket motors.** S. S. PENNER. *J. Amer. Rocket Soc.*, **23**, 85–88, 98 (*March-April*, 1953). Upper limits are estimated for the rate of evaporation of small liquid droplets in rocket combustion chambers assuming the droplets to be isothermal. (20 *refs.*)

(256) **Volumetric behavior of red and white fuming nitric acid.** H. H. REAMER, D. M. MASON and B. H. SAGE. *Industr. Engng. Chem.*, **45** 1094–1097 (*May*, 1953).

REVIEWS

The Real Book about Space Travel

(By Hal Goodwin. Garden City Books, Garden City, New York. 1952. 192 pp. Price $1·25.)

This is an ideal book for the teenager, and the author is to be congratulated for the reserved way in which he presents this subject—so often treated in a careless manner in popular magazines. The text is clearly and attractively written and the various topics are dealt with in a chronological and conventional order.

The book is directed at American youth for the author makes reference to the many Radio and T.V. programmes dealing with "Flash Gordon" type of adventure in space. However, his method of disposing of their many impossible antics is very pleasing. This constant comparison of the facts with both good and bad Science Fiction may seem unnecessary to the adult, but should help the youngsters to see things in their true perspective. The author wisely points out that the people who say space travel is easy and already practically achieved are more of a hindrance than a help.

A major disappointment is that the standard of the illustrations is poor, and the purpose of some of them is not altogether clear.

The information given is generally sound and correct, and for a book of its class is as up-to-date as one can be in this particular subject.

P. R. FRESHWATER.

Rockets Beyond the Earth

(By Martin Caidin. Published at $4·50 by the McBride Co. (N.Y.). 304 pp., profusely illustrated by photos and drawings.)

This is yet another of the current crop of popular works intended to explain to the layman "that Man is now on the verge of travel into outer space". (While agreeing with any reasonable interpretation of that statement, this

reviewer cannot help wondering whether the man-in-the-street is not being encouraged to take it rather too literally. He may well feel a sense of anti-climax at some point during the next generation or two, which must pass before Man can actually hope to *land* on the Moon, as against merely reading about that exciting possibility.)

However, *Rockets Beyond the Earth* is a good deal better than many of its predecessors in the same field, though one could not fairly say it is as good as the best. Readers will obtain a substantially accurate impression of the current status of astronautics, the achievements of rocketry to date and the best thought on probable future lines of progress, etc. The style of the book is simple and straightforward—even naïve, in places. For example, it begins somewhat inauspiciously with a frontispiece showing a spaceship well and truly "pranged" on the Lunar surface, bearing the not-very-encouraging caption: "The survivors have only hours to live—death will overtake them when their oxygen is gone." In view of the author's obvious enthusiasm for space-flight, this comes close to masochistic gloating, and the same might be said of an horrific illustration on p. 215: "This spaceman was caught in the fury of a rocket attack against his satellite and was blown away from Earth with tremendous speed. His dead body, frozen and battered, will drift endlessly in the void unless the gravitational force of a large planetary body draws it in—smashing the corpse on the surface of a planet or moon."

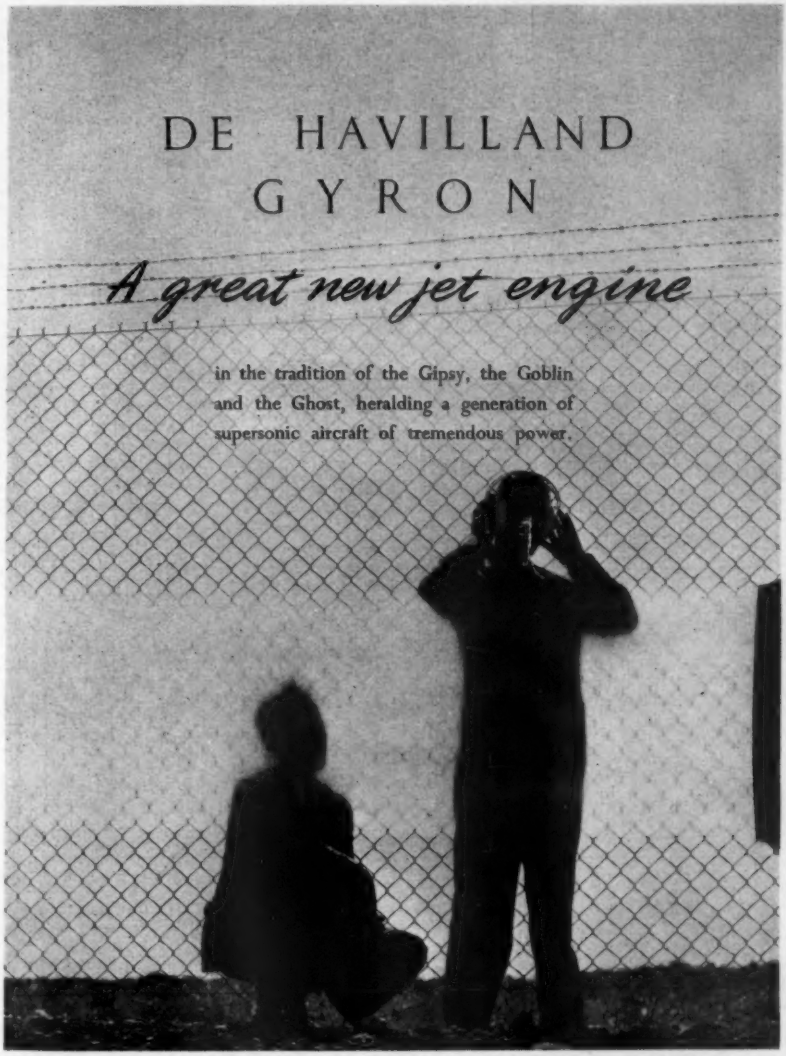
Quite the worst thing about the book, especially in view of the fact that its main attraction is likely to be for a juvenile audience, is its obsession with the military and political aspects of satellite vehicles and Lunar bases. This adolescent approach has been altogether too prevalent across the Atlantic since the war, and should hardly be encouraged by such statements as:

". . . the first satellites about the Earth will be established under control of the military; there is no reason why this line of thinking should vary for Lunar bases" (p. 262) and: "We can prevent Soviet moon bases *only* if we move quickly and push our rocket programmes" (p. 272).

These two quotations are quite typical of dozens of similar observations in the text. However, it is only fair to mention that in Chapter XVI ("The Challenge") Mr. Caidin does at least express regret and distaste for the point of view which he has apparently accepted, and invites Mankind to look towards a more civilized and hopeful alternative. Also, on p. 256, he says: "If our own nation—with technical assistance and other aid from our friends in Great Britain—becomes the leader in space exploration, then I believe there will be fair and just space laws," and certainly he implies throughout that he hopes this will be so.

One of the best aspects of the book is its excellent illustrations, mostly in the form of black-and-white drawings by Fred L. Wolff and Jerry J. Schlamp. Many of these were obviously suggested (to put it mildly) by other sources, but any accusation of plagiarism is weakened by the fact that an acknowledgement is usually made at least to the originator of the idea, or project, depicted.

A. V. CLEAVER.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